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The Performance of Gas Furnaces in Five Well-Insulated Houses

A RESEARCH REPORT

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A RESEARCH REPORT

A Field Study of Gas Furnace Performance in Relation to Furnace Sizing and Space Heating Load

Sponsored by the
Energy Conservation and Oil Substitution Branch
Energy, Mines and Resources Canada

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under a sub-contract from the
Saskatchewan Research Council

October, 1982

BETT Publication No. 82.07

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Cat. No. M91-3/82-07E
ISBN 0-662-12822-2

ABSTRACT/RESUME

An investigation has been conducted on the relation between furnace oversize and seasonal efficiency. Five houses, containing natural gas furnaces with oversize factors ranging from 34% to 133%, were selected for the investigation and measurements were taken of various furnace performance parameters. It has been shown that the performance of the furnace is affected substantially by many factors, including the anticipator setting, thermostat type and location, and configuration of the air distribution system. These factors, which varied considerably from one house to another, made it difficult to isolate the correlation between furnace oversize and seasonal efficiency.

* * *

La présente étude porte sur les rapports qui existent entre une chaudière surdimensionnée et le rendement saisonnier de cette chaudière. Cinq résidences munies de chaudières au gaz naturels surdimensionnées dans une proportion de 34% à 133% ont été choisies aux fins de l'étude, et les divers paramètres de rendement de ces chaudières ont été mesurés. L'étude a révélé que de nombreux facteurs, y compris le réglage du dispositif d'anticipation du thermostat, le type de thermostat choisi, son emplacement, ainsi que la configuration du système de distribution d'air, influent considérablement sur le rendement de la chaudière. Ces facteurs, dont l'influence varie considérablement d'une résidence à l'autre, ont compliqué l'étude distincte des rapports entre la surdimension et le rendement saisonnier des chaudières.

Le lecteur trouvera un sommaire en français de ce rapport à la page iii.

TABLE OF CONTENTS

	PREFACE	i
	ACKNOWLEDGEMENTS	ii
	SOMMAIRE	iii
1.	INTRODUCTION	1
2.	METHODOLOGY	
3.	SAMPLE SELECTION	
	Survey House Selection	2
	Study House Selection	5
4.	INSTRUMENTED MONITORING	
	Calibration	9
	Initialization	9
	Continuous Monitoring and Data Collection	11
	Single Interval Tests	15
	Anticipator Adjustment	16
5.	DATA REDUCTION AND ANALYSIS	
	Decay Heat Loss	20
	Furnace Cycles per Day	21
	Furnace Cycles per Degree Day	24
	Megajoules per Day	29
	Megajoules per Volume	32
	Megajoules per Degree Day	34
	Megajoules per Volume per Degree Day	36
6.	SUMMARY ANALYSIS	38
7.	CONCLUSIONS	46
8.	BIBLIOGRAPHY	50
	APPENDIX A: Study House Data	
	APPENDIX B: Thermograph Records for Study Houses	
	APPENDIX C: Regression Analyses	
	APPENDIX D: Communication to Insulation Contractors and Homeowners	
	APPENDIX E: Heating Load Analyses for Houses Surveyed	

FIGURES & TABLES

FIGURES

Figure 1: Preliminary Survey Data Form 4

Figure 2: Building Load/ Heat Loss Output Form 6

Figure 3: Furnace Oversize: Houses Surveyed 7

Figure 4: House and Furnace Data Form 14

Figure 5: Furnace Cycle Sample Record 18

Figure 6: Furnace Cycle Sample Record 19

Figure 7: Furnace Cycles per Day 23

Figure 8: Furnace Cycles per Degree Day 28

Figure 9: Megajoules per Day 30

Figure 10: Megajoules per Volume 33

Figure 11: Megajoules per Degree Day 35

Figure 12: Megajoules per Volume per Degree Day 37

Figure 13: Average Weekly Interior Temperatures 40

TABLES

Table 1: Summary of Heating System Adjustments 12

Table 2: Furnace Rated and Measured Efficiencies 15

Table 3: Decay Heat Loss Tabulation 20

Table 4: Furnace Cycles per Day 22

Table 5: Meteorological Summary - March 1982 25

Table 6: Meteorological Summary - April 1982 26

Table 7: Furnace Cycles per Degree Day 27

Table 8: Megajoules per Day 29

Table 9: Megajoules per Volume 32

Table 10: Megajoules per Degree Day 34

Table 11: Megajoules per Volume per Degree Day 36

Table 12: Summary of Furnace Performance 43

With the trend towards houses of increasing energy efficiency, the space heating requirements of the houses are becoming progressively smaller and there is a consequent tendency for furnaces to become oversized. When a furnace is oversized, ie. when its output capacity is greater than the heating load of the house, it suffers a reduction in seasonal efficiency. The effect is of particular importance in residential retrofit, where the furnace may be oversized to begin with, but after retrofit may be oversized by a much greater factor - sometimes as much as three times the required capacity.

The purpose of this study was to measure the performance of furnaces in a sample of five houses where the furnaces were known to have a range of oversize factors. By careful measurement it was hoped to determine the seasonal efficiency of each furnace, and then obtain a correlation between seasonal efficiency and oversize factor.

The study failed to achieve this objective because of the complexity of the physical processes that determine furnace performance. The seasonal efficiency of a furnace is determined partly by the furnace cycling mode. This, in turn, is determined not only by the oversize factor but also by a range of other factors: thermostat type, anticipator setting, thermostat location, fan limit control settings, design of the air distribution system, etc. These factors varied considerably from house to house, and therefore confounded any attempts to obtain a systematic correlation between oversize factor and seasonal efficiency.

In spite of this, the report is of considerable value in identifying and quantifying some of the secondary factors that affect furnace seasonal efficiency. It follows, from this report, that if furnace seasonal efficiencies are to be studied in a real-life situation, the results will be inconclusive unless there is some considerable refinement of measuring techniques and a far greater control of all the variables.

The report shows how little is really known about furnace performance in a real-life situation, and by implication stresses the need for a more concerted applied research effort in this direction.

D. Eyre
Saskatchewan Research Council
June, 1983.

The authors wish to express gratitude to the homeowners and occupants of the study houses, whose patience and cooperation over the monitoring period is greatly appreciated.

Recognition is also extended to the Society of Alberta Home Insulators (SAHI) contractors who assisted in compiling preliminary information on potential study houses and to Housing and Urban Development Corporation (HUDAC), Alberta Chapter, for their cooperation in providing access to the 1981 Parade of Homes: Energy Conserving Show Homes.

To our colleagues, the residents at the Kananaskis Centre for Environmental Research, a special note of thanks for their ongoing support and cooperation in the development of techniques and methodology for Home Energy Surveys, and to John Corbin and Trish Harrison for their valuable typing and editorial input to the preparation of the final report.

La présente étude pilote a pour objet le rendement des chaudières au gaz à chauffage par air pulsé d'un groupe choisi de résidences nouvelles et existantes dont l'isolation thermique est supérieure à la moyenne.

L'étude traite des chaudières surdimensionnées (dont la capacité thermique excède la charge calorifique de la résidence aux températures hivernales de calcul) par rapport à son rendement saisonnier.

La fréquence des cycles de fonctionnement, la durée totale du fonctionnement par jour, le rapport entre les cycles de fonctionnement et les degrès-jours, et le nombre de mégajoules par volume par degré-jour ont été mesurés ou calculés de manière à servir d'indicateurs du rendement saisonnier de la chaudière.

Les résultats de l'étude indiquent une prologation évidente des cycles de fonctionnement des chaudières de certaines des résidences échantillonnées. Ce phénomène peut nuire au rendement de la chaudière. Les données indiquent que la réduction des déperditions de chaleur de l'enveloppe du bâtiment peut avoir un effet sur les cycles de fonctionnement, la chaudière se révélant ainsi surdimensionnée. Toutefois, d'autres facteurs tels que le réglage du dispositif d'anticipation du thermostat, le réglage des contrôles de ventilation, la vélocité de l'air, la configuration du système de distribution d'air chaud, l'isolation thermique de la conduite d'air comburant et de la chaudière ainsi que l'emplacement du thermostat peuvent avoir une incidence importante sur ce phénomène de la surdimension et ainsi, sur le rendement de la chaudière.

Les rapports entre tous les facteurs influant sur le rendement saisonnier de la chaudière devraient faire l'objet de recherches supplémentaires.

1. INTRODUCTION

Many factors contribute to furnace efficiency in residential buildings. The heating requirements of the building at outside temperatures close to heating season minimum temperature (winter design temperature) should form a consistent basis for calculating the requisite capacity of the furnace prior to installation. However, many residential buildings are equipped with furnaces whose output exceeds the heating requirements of the structure. This may have significant effects on seasonal heating costs.

Where the house structure has been improved to reduce heat loss and achieve more efficient operation (i.e. adding insulation, sealing air leaks), symptoms of furnace oversize may be evident. This condition exists when the reduced heating requirements of the house results in rapid, short, furnace burn cycles. In some cases, this causes an increase in daily fuel consumption, and seasonal reductions in furnace efficiency.

The objective of this study is to determine gas furnace performance as a function of the rated output of the furnace, and the calculated space heating load of the house at design temperature.

Information for the initial Home Energy Survey house sample selection was obtained with the cooperation of the Society of Alberta Home Insulators (SAHI) contractors, and Housing and Urban Development Association of Canada: Alberta Chapter (HUDAC) builders.

Five houses which met the criteria for a range of rated oversize were selected for a four week intensive pilot study during March and April, 1982. The study used a house survey approach, based on the Home Energy Survey methodology developed by R. Argue and Millbank Associates (1981). Modifications to the Millbank methodology included adaptation to local conditions with a focus on information transfer to the homeowner, as well as providing a consistent framework for data collection compatible with the computerized analyses used.

Calculations for determining actual building heat load are based upon techniques as presented in the ASHRAE Handbook of Fundamentals, and calculated in a computer program written by Dumont and Hamlin (1980). This calculated load and furnace output capacity, as rated on the furnace specification plate, are input to determine furnace oversize using the calculation described by Quirouette and Sheuneman (1981).

Implicit in the objectives of this pilot study was the development of a simple, cost effective methodology for assessing furnace performance as it relates to furnace oversize. The following section documents this methodology in the context of sample selection, instrumented monitoring and data analysis for this study.

Survey House Selection

The first stage of the study involved a search for potential study homes which had recently added considerable insulation to ceilings, basement, or walls. This was accomplished through telephone contacts with local insulation contractors, who agreed to compile lists of six to twelve recent clients, with addresses and homeowner names, as well as the amount and location of insulation added to each house. It was agreed that this list would be exchanged for a letter to briefly explain the study. All insulation contractors contacted for this information are members of the Society of Alberta Home Insulators (SAHI), a professional association of insulation contractors. The lists from these contractors were organized into a short directory and reviewed for potential study homes.

Through the Housing and Urban Development Association of Canada, Alberta Chapter (HUDAC), information on the 1981 HUDAC Energy Conserving Show Homes was made available for the study. All of these houses had been built with greater than average insulation levels, which could potentially result in a condition of furnace oversize. Contacts with builders were established to gain access to the unoccupied Show Homes.

The assumption was made that the houses with the greatest amount of insulation would exhibit the greatest sensitivity to furnace oversizing. A letter of explanation and request to collect data was then hand-delivered to these homes. This was immediately followed up by a telephone contact with each homeowner to arrange a convenient time to visit the house. Eleven houses were selected for the preliminary audit/survey to compile information for furnace oversize calculation. This study used a home energy survey modified from the procedure developed by Ron Argue and Millbank Associates (1981).

The survey began with a short meeting with the homeowner to explain the data collection procedure. Following this, dimensions of outside walls and windows were documented. Wherever possible, outside measurements were preferred over inside measurements in order to minimize interference with household activity. The final stage of data collection was inside the home. Insulation levels and energy related interior conditions were noted as well as anomalies and idiosyncracies observed by the survey team or noted by the homeowner. A thermometer was left to stabilize on top of the thermostat while information was collected from the furnace specifications plate. Figure 1 illustrates the data collection form used in the survey. Where furnace specifications or thermostat calibrations were measured in imperial units, these data were recorded on the data collection form, and converted to SI metric units for calculation and presentation in this report.

Each home energy survey was completed in approximately one hour by a two-person survey team. The two-person team is particularly effective for data gathering and information transfer to the homeowner. This reduces the additional time spent at each house in those cases where the homeowner is either interested in the study or wishes specific information to further upgrade the energy performance of the house.

RESIDENTIAL ENERGY SURVEY FORM

ADDRESS/ CITY/ PROVINCE:

OCCUPANT NAME/ TELEPHONE # :

OCCUPANCY:

YEAR HOUSE BUILT/ REMODELLED: PRESENT R VAL OF CEILING:

HOUSE FORM/ SHAPE:

HEATED LIVING AREA (M2): INCLUDES BASEMENT (Y/N):

THERMOSTAT SETTING:

HEATING SYSTEM TYPE:

MAKE/ MODEL/ YEAR INSTALLED:

DIRECTION	WALLS L*H (M):R VAL	WINDOWS L*H (M):R VAL	DOORS L*H (M):R VAL	NET WALL AREA (M):R VAL

PERIMETER (M) = TOTAL WALL LENGTH:

BASEMENT FLOOR AREA:

BELOW GRADE HT(M): R VAL ABOVE GRADE HT(M): R VAL WINDOW AREA (M2):R VAL

HEATED VOLUME = AREA x TOTAL HT OF HEATED WALLS:

AUXILLARY HEATING:
COMBUSTION AIR:
DRYER VENT:
DHW:

COMMENTS:

Figure 1 Data form for preliminary survey of potential study houses.

Study House Selection

Data gathered by the survey process were input to a computer program to perform a heating load calculation at design temperature. This analysis procedure has been adapted from programs developed by Dumont and Hamlin (1980) and modified by M. Youso, Kananaskis, for local climate and housing. The parameters calculated by this program are listed on the output form shown in Figure 2.

In addition to the data collected during the house survey, program input assumed a design temperature differential of 55.5 deg. C (100 degrees F), and an air exchange rate of 1 air change per hour. This conforms with the established practice of local heating systems contractors for sizing residential furnaces. Two additional analyses were made for each house surveyed. One analysis calculated heating load at the estimated air exchange rate and interior temperature as measured during the survey. The other analysis assumed an infiltration reduction to 0.8 air change per hour and a nighttime temperature set back to 15 degrees Celsius, as could be expected with upgraded weatherstripping and a timer controlled setback thermostat. The heat loss analyses for each house, and a comparative summary of annual energy cost for the three sets of input assumptions, were returned to the homeowner, along with a letter thanking them for participating in the study.

The percent of furnace oversize was determined by total heat loss, as calculated at design temperature and 1 air change per hour, and the furnace rated output from the specifications plate on the furnace. The following equation was used for the calculation (Quirouette and Scheuneman, 1981).

$$\text{furnace oversize} = \frac{\text{furnace rated output} - \text{building heat loss}}{\text{building heat loss}} * 100$$

The results of this calculation for the houses surveyed is shown in Figure 3.

```
                    BUILDING ENERGY DESIGN ANALYSIS

A program to calculate theoretical heat loss of low energy buildings,
modified from NRC DBR-R. Dumont(1981) by U of C KANANASKIS-M. Youso

************************** DESIGN INPUT DATA ****************************

SRC TASK 5  FURNACE PERFORMANCE EVALUATION

DESIGN TEMPERATURE: -33 DEGREES CELSIUS
MAIN FLOOR TEMP 22.5    BASEMENT TEMP  20   GROUND WATER TEMP  4
DESIGN TEMP DIFF (ABOVE GROUND) 56 (BELOW GROUND) 16 DEG C

*****U of C  KANANASKIS CENTRE*******BUILDING ENERGY DESIGN ANALYSIS*****


ELEMENT                 AREA          RSI VALUE        HT LOSS       SEASONAL
                         M2           M2-DEGC/W        W/DEG C       % HT LOSS

CEILING
WALLS
WINDOWS-S
WINDOWS-NON S
DOORS
BSMENT,AB.GD.
BSMENT,BL.GD.
FLOOR
AIR CHANGE              ----             ----

BUILDING VOLUME(M3)=            AIR CHANGE/HR: HEATED=          TOTAL=

 HT LOSS ALL WINDOWS             (W/DEG C)
 HT LOSS ABV GND,EXCL ALL WINDW (W/DEG C)
 HT LOSS BELOW GRADE WALLS       (W/DEG C)
 HT LOSS BELOW GRADE FLOOR       (W/DEG C)

 TOTAL HT LOSS: EFFECTIVE UA     (W/DEG C)

 AVG HT TRANSMITTANCE ABV GND   (W/M2-DEG C)

TOTAL HEAT LOSS        (WATTS)        (BTU/HR)  AT DESIGN TEMP: -33 DEG C

VOLUME FOR THE BUILDING (CUBIC METRES)          M3= CU. FT./35.31
AREA FOR ELEMENT OF THE BUILDING (SQ. METRES)   M2= SQ. FT./10.76
HEAT RESISTANCE OF ELEMENT (M2-C/W)            RSI= R/5.678
HEAT LOSS OF ELEMENT (WATTS)        WATTS * 3.413 = BTU/HR
```

Figure 2 Output format for the design temperature heat loss calculation.

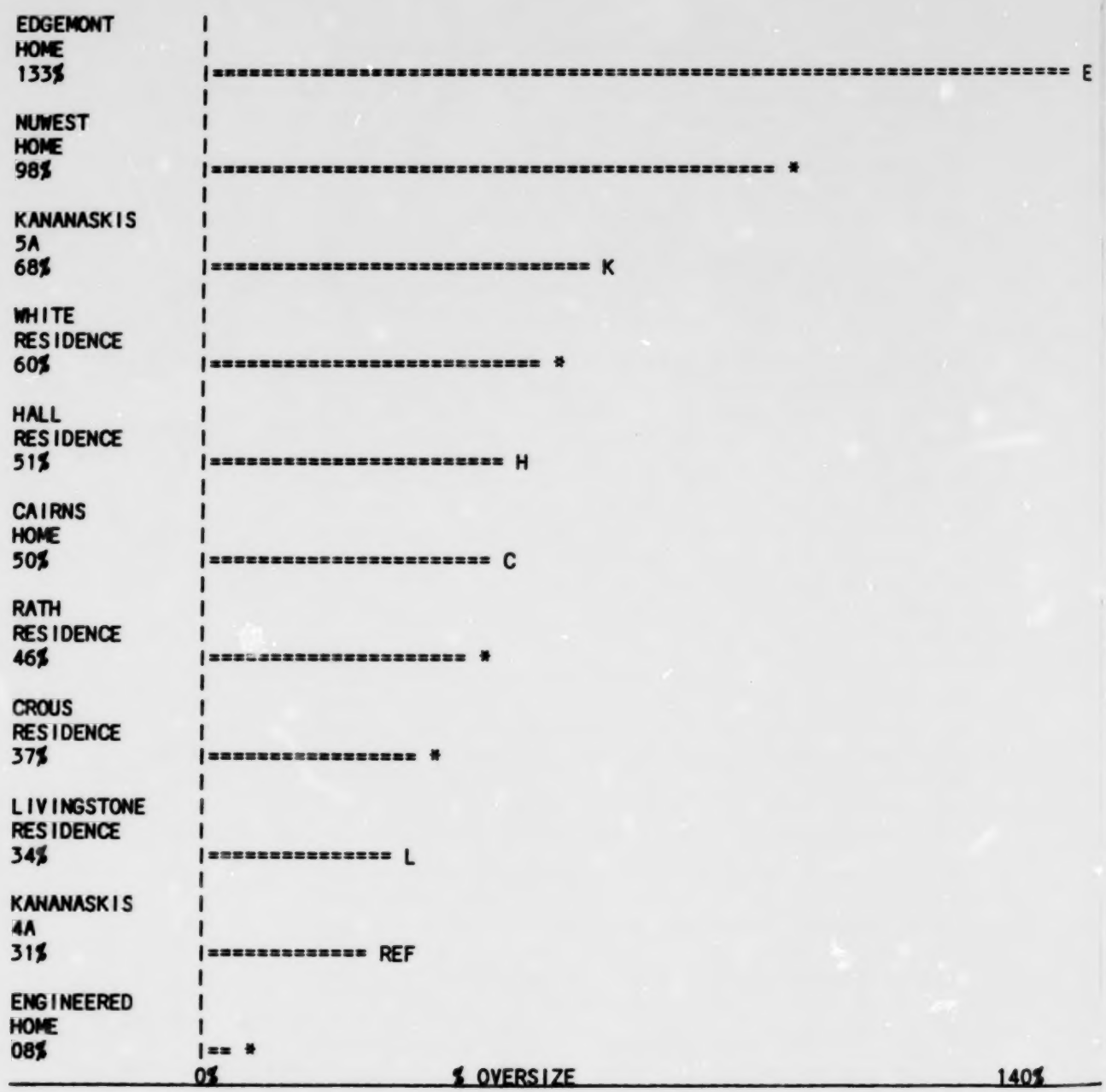


Figure 3

An illustration of the results of furnace oversize calculations for the eleven houses surveyed. The samples are arranged in ascending order of percent furnace oversize. Houses selected for the study are shown with the letter code used throughout the graphic analysis. Kananaskis 4A is used as a reference house for the study.

From this distribution of furnace oversize, five houses were selected to represent the five categories of furnace oversize criteria as specified for this study. For final house selection based on furnace oversize criteria, those houses which were occupied by owners of insulation companies who participated in the initial survey were given the first opportunity to have the detailed study performed on their house. These selected houses received an expanded letter describing the data collection procedures relating to the requirements of this project.

Samples of letters sent to the insulation companies and homeowners who participated in the Home Energy Survey and the Furnace Performance Evaluation are included in Appendix D.

Two of the houses (Edgemont and Cairns) selected for the study were new, unoccupied, energy conserving homes. These two adjacent houses, with greater than average levels of insulation and air tightness, and identical flueless condensing furnaces, offered a unique opportunity for comparative study.

Calibration

The next phase of this study involved the preparation of temperature and furnace-cycle recording equipment for monitoring the test houses. To monitor inside temperature and relative humidity, Lambrecht Type 252 Hygrothermographs with seven day clock chart drives were calibrated in the laboratory for two days with a reference thermometer and a sling psychrometer. To monitor furnace on/off cycles, Rustrak Series 8363 Mini Chart Recorders, with 2.54 cm. (1") /hour strip chart clock drives, were modified with a custom built electronic circuit to measure 0 to 100 volt A.C. signals. Furnace cycle recording instruments were connected in parallel to the gas valve solenoid on each of five furnaces at the Kananaskis Centre for twenty-four hours prior to field testing to insure that all instruments were functioning correctly.

Initialization

Subsequent to instrument test and calibration, appointments were made with homeowners, and sets of instrumentation were installed in the four Calgary test houses. One set remained in Kananaskis house 5A.

To provide data on temperature decay rates and to approximate average living conditions for both occupied and unoccupied houses, all houses were equipped with setback thermostats. In consultation with the homeowners, similar time/temperature schedules were programmed into the thermostats of all the houses studied. The temperature setback schedules are documented on the house data forms in Appendix A.

For those houses equipped with setback thermostats prior to the study, the anticipator setting was recorded and left as set. In the Hall and Livingstone residences, new thermostats (Robertshaw T30-1041) were installed, with the anticipator adjusted to the setting of the original thermostat. All setback thermostats were levelled when installed.

Replacement thermostats were installed with the homeowner's cooperation and the understanding that this thermostat would be retained by the homeowner at the conclusion of the study. After five days one thermostat was found to be defective. The homeowner re-installed the original thermostat on 15 March. A replacement setback thermostat was installed on 22 March. The replacement unit performed well for the remainder of the test period.

Prior to the test period, three of the houses had been operating with the furnace fan running continuously. The results of tests performed at Oak Ridge National Laboratory by Hise and Holman (1977) show that furnace fan controls and blower cycling have a significant effect on the efficiency of gas-fired, forced-air furnaces. The higher the temperature at which the furnace fan begins circulating air through the heat exchanger, the greater the amount of heat whuch will be lost up the flue prior to air circulation. In a similar manner, if the fan stops circulating air past the heat exchanger before the heat exchanger temperature reaches a balance with room temperature, then heat retained in the heat exchanger is lost up the flue. These losses can be avoided if the fan is left on continuously.

Since this study addresses the question of the effects of furnace oversize, the experimental design isolates the oversizing effects from those caused or influenced by fan switch settings. To comply with requests of the homeowners and to eliminate this as a variable in the study, all fan on/off control temperature settings were recorded as set and bypassed with the fan switch on continuously. The new furnaces in the Cairns and Edgemont houses are supplied with two speed fans which run continuously on low speed and switch to high when the burner is on. Gas valve safety limit switches were not adjusted. Limit settings were recorded on the data form.

Continuous Monitoring and Data Collection

For ease of assembling and documenting data, the schedule for thermograph chart changing was conducted at all test houses on a specified day each week. This weekly contact was valuable for several reasons:

1. Instrumentation check: data loss due to instrument malfunction or failure was reduced to a maximum of seven days.

2. Furnace performance check: furnace cycling chart for each week was inspected on each visit to qualitatively determine heating system performance.

3. Heating System adjustments: setback thermostat schedules and anticipator setpoints were adjusted and any changes were recorded. A summary of these adjustments is included in Table 1.

4. House performance check: feedback and response from occupants was an essential parameter in determining human comfort levels with temperature setback schedules. It was emphasized that occupants should make any necessary adjustments to optimize comfort, with the understanding that the reseachers would be kept informed of the timing and nature of the adjustments.

A major factor in the success of conducting such a study on occupied houses is the development of a good rapport with homeowners. It is essential that the research activity does not alter the lifestyles of the occupants during the study. The friendly, neighbourly attitude maintained between researchers and homeowners provided a mutual understanding of the study. The weekly visits allowed time for questions and discussion which provided valuable background information on lifestyle and anomalous conditions for subsequent data analysis and evaluation.

Table 1 Summary of Heating System Adjustments

	LVN	HALL	CAR	KNA	EDG
WEEK 1					
setback thermostat	installed	installed (defective)	installed	installed	installed
schedule: time/temp	0500/22.5 2330/15.0	0600/22.5 2400/15.0	0600/22.5 1000/15.0 1630/22.5 2400/15.0	0500/20.0 2300/15.0	0600/22.5 1000/15.0 1630/22.5 2400/15.0
anticipator setting	0.35	0.35	0.70	1.00	0.35
WEEK 2					
		defective thermostat replaced w/ original non-setback		occupant set t'stat back to 24 hr. temp. of 19 deg C	
WEEK 3					
		thermostat replaced w/ operative setback unit		reset t'stat to setback 0500/20.0 2400/15.0	
WEEK 4					
anticipator:	reset 1.0	reset 1.0	reset 1.0		reset 1.0

Conditions of continuous or intermittent short cycling were noted in the Livingstone and Hall residences and the Edgemont Home. It was noted that the furnace in the Hall residence cycled up to 280 times per day. The rapid cycling occurred prior and subsequent to the installation of a properly operating setback thermostat. During the initial survey, the occupants had noted that the thermostat required a set point two or three degrees Fahrenheit above the desired temperature. The design of the original thermostat did not allow for bubble level checking. With the agreement of the homeowner, a representative from the local gas utility was asked to inspect the furnace for proper operation of the gas valve and safety limit switch. The technician's inspection indicated that the furnace was operating correctly, and that the recording instrumentation was not affecting the gas valve operation. All other furnaces appeared to operate correctly.

HOUSE DATA

CASE:.....

CONSTRUCTION TYPE:.....

FORM:.....

HEATED FLOOR AREA (M2):.....

YEAR BUILT:.....

OCCUPANCY:.....

STOVES:.....

ELECTRIC HEATING DEVICES:....

FLUES:.....

FIREPLACES/ DAMPERS:.....

APPARENT MOISTURE SOURCES:...

ANOMALIES & IDIOSYNCRASIES:

FURNACE DATA

MAKE/ MODEL; YEAR INSTALLED:

Rated output BTU/H :

AIR HANDLING SYSTEM

TEMPERATURES (deg C): SUPPLY DUCT (BONNET): ; RETURN AIR:

AIRFLOW (M/s, CFM): SUPPLY DUCT (BONNET): ; RETURN AIR:

BLOWER MOTOR SIZE: hp RATED CFM:

FAN CONTROL (deg F): ON: OFF: LIMIT: fan switch on

RESET: ON: OFF: LIMIT:

STEADY STATE COMBUSTION EFFICIENCY

PERCENTAGE EFFICIENCY: BACKDRAFTING (Y/N):

PERCENT OXYGEN: STACK TEMPERATURE (deg C):

THERMOSTAT

TEMPERATURE SCHEDULE:

INITIAL ANTICIPATOR SETTING: RESET: DATE:

Figure 4

Data form for house characteristics and steady state furnace performance. The (Y/N) indicates a "yes or no" choice for flue backdrafting.

Single Interval Tests

Detailed house data and steady state furnace performance data were collected and tabulated on the form shown in Figure 4. The completed data forms for the houses surveyed are included in Appendix A.

To measure steady state operating characteristics and combustion efficiency of the furnaces, the thermostat was bypassed and the furnace operated for a minimum of ten minutes prior to the measurements. Stack (flue gas), supply duct (bonnet), and return air temperatures were measured with a mercury thermometer (ASTM specification E1). Percent oxygen in the flue gas was measured with a Fyrite Gas Analyzer. Combustion efficiency of the furnaces was calculated using percent oxygen, stack temperature, and combustion data for natural gas. Combustion characteristics for natural gas used in Calgary were provided by Canadian Western Natural Gas. The time in seconds for one cubic foot of natural gas (one megajoule) to pass through the meter was measured with a stopwatch. All other gas burners were off during this measurement. These data were used to calculate the fuel input for each furnace in megajoules per hour. Furnace age, rated specifications, and energy inputs and outputs as measured and calculated are shown below in Table 2.

Table 2 Furnace Rated and Measured Efficiencies

	LVN	HAL	CAR	KNA	EDG
FURNACE MFCTR. & MODEL	Chrysler 4212-10H	Furnace Aire 125 FLBK	Clare HEG 80	Lennox G8R82T	Clare HEG 80
FURNACE INSTALLED (YR)	1969	1959	1981	1968	1981
PERCENT OVERSIZE	34	51	50	68	133
RATED OUTPUT (BTU/HR)	86400	100000	67000	65600	67000
RATED OUTPUT (MJ/HR)	91	105	71	69	71
MEASURED INPUT (MJ/HR)	103	111	80	66	80
MEASURED EFFICIENCY (%)	78	75	87	74	88
CALCULATED OUTPUT (MJ/HR)	80	83	70	49	70

A Kurz Model 410 hot wire anemometer was used to measure the return and supply duct velocities at the point were the ducts connect to the furnace. These data and the cross sectional duct area at the point of velocity measurement were used to calculate the tabulated CFM values. With the gas valve off and the heat exchanger at return air temperatures, the stack was checked for the presence of backdrafting.

An AGAtronics Model TPT 80, non-contact, digital-output, portable infrared thermometer was used to measure the mean radiant temperature of each of the heated rooms in the test houses. These data along with schematic plans of the house interiors are included in the house data sections of Appendix B. Detailed heat loss calculations for the test houses are found with the temperature data and house and furnace data in Appendix B.

Anticipator Adjustment

Many heating system thermostats incorporate an adjustable anticipator which usually has an adjustment range from zero to one milliamperes. The anticipator should be adjusted to a setpoint which corresponds to the milliampere load of the gas valve/thermostat circuit.

The function of the anticipator is to provide localized preheating of the bimetallic sensor in the thermostat to reduce temperature overshoot in a forced air heating system. The control of temperature overshoot by the anticipator directly affects the firing rate of the furnace. Reducing the anticipator setting to zero minimizes temperature overshoot and may also cause short cycling of the furnace, particularly if the furnace is oversized. An oversized furnace may deliver a large volume of hot air which will satisfy the room thermostat before it heats the room surfaces. Increasing the anticipator setpoint above zero will decrease the effect of the anticipator in limiting temperature overshoot. However, such an adjustment may eliminate a short cycling condition.

In many cases, conditions of short cycling may be more sensitive to anticipator adjustment than to furnace oversize.

To test for conditions of short cycling as a result of anticipator adjustment, the anticipator setting for all the study houses was set to 1 after three weeks of continuous monitoring. In the Kananaskis house, the anticipator had been set to 1 prior to the study and it was not adjusted. Sample records from the furnace monitoring instruments are illustrated in Figure 5 and 6. Records of before and after the anticipator reset are included. In the Hall and Edgemont cases, this adjustment of the anticipator stopped the rapid cycling condition. In the case of the Livingstone residence, adjusting the anticipator did not change the length of furnace burn cycle as measured with a stopwatch, however, resetting the gas valve limit switch from 43.3 to 93.3 deg C (110 to 200 deg F) eliminated the rapid cycling condition. In the Cairns house, no change in furnace performance was noted with the anticipator reset to 1. The recording instrumentation was left in place for an additional week of data collection after these adjustments had been made. The only example of a temperature rise above the thermostat setpoint (2 deg C) occurred in the Edgemont house after resetting the anticipator to 1.

The thermostat anticipators were reset to 0.5 in the Calgary test houses and the recording instrumentation removed at the conclusion of the test period. Two of the furnace cycle recorders were then installed in houses at Kananaskis for one additional week. The strip chart and thermograph records for these reference houses are included with the furnace cycle records from the test houses in the Appendices.

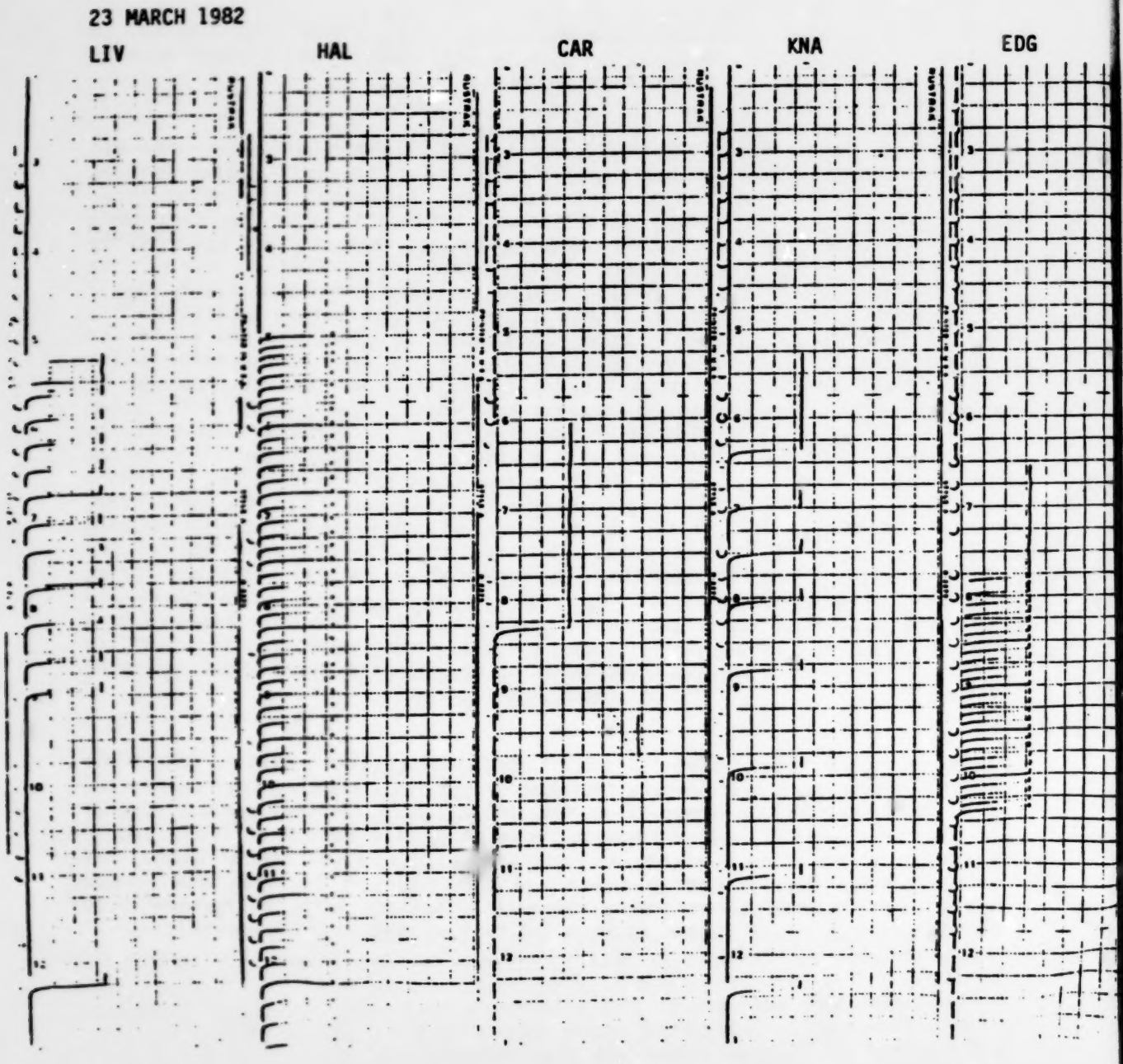


Figure 5

A sample of furnace cycle records for the study houses prior to adjusting the thermostat anticipator to 1. The early morning portion of the daily record is shown.

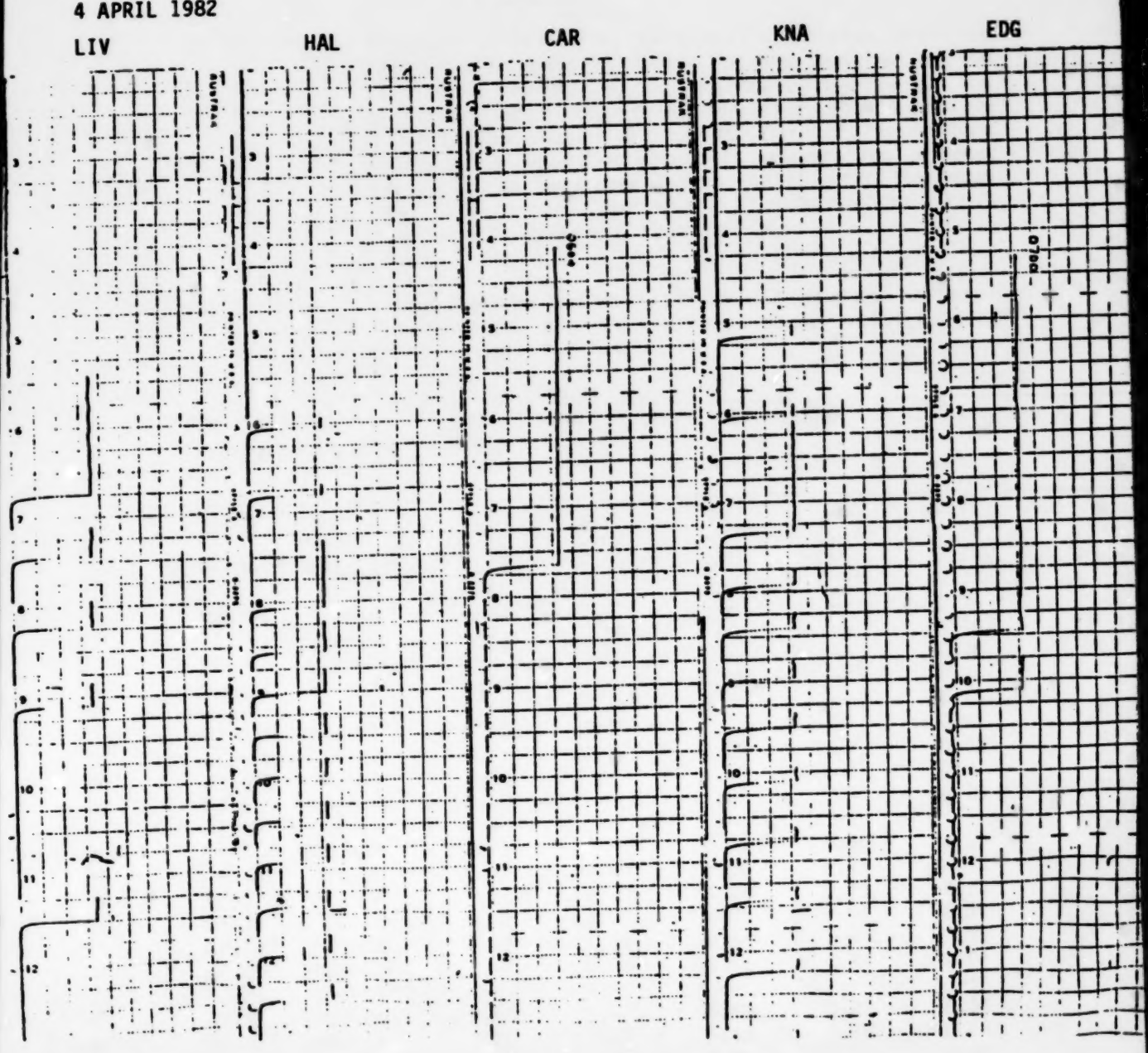


Figure 6

A sample of furnace cycle records for the study houses after adjusting the thermostat anticipator to 1. The early morning portion of the daily record is shown.

Decay Heat Loss

A recent study by White (1981) indicates that the rate of heat decay following furnace shutdown may be related to the thermal performance of the house. The hygrothermograph records for the study houses provide a continuous measurement of the rate of temperature decay, as a result of automatic temperature setback. These records have been abstracted to determine decay heat loss in deg. C per hour. The hygrothermograph records are included in Appendix B.

Table 3 below shows minimum and maximum outside temperatures, and the nighttime decay heat loss (deg C/hr) for all the houses.

Table 3 Decay Heat Loss

DAY # (from Jan.01)	TEMP. ATM (C) Calgary:Kananaskis MAX	MIN	NIGHTTIME TEMPERATURE DECAY RATE (DEG C/HR) LVN	HAL	CAR	KNA	EDG
67	02:05	-15:-10	0.40	0.60	1.03	0.66	0.76
68	07:07	-03:01	0.38	0.68	1.15	0.84	0.78
69	04:04	-08:-09	0.39	0.63	1.05	0.80	0.76
70	07:04	-06:-06	0.44	0.61	--	0.55	0.76
71	02:-01	-09:-07	0.52	0.55	--	--	0.76
72	05:00	-06:-09	--	0.60	--	--	0.76
73	00:-01	-07:-08	--	--	--	--	0.76
74	00:-01	-05:-07	0.45	--	0.90	--	0.76
75	-01:-03	-07:-11	0.45	1.18	1.05	--	0.76
76	-04:-05	-13:-08	0.68	1.33	1.75	--	0.97
77	-07:-05	-19:-22	0.53	0.37	1.25	--	0.85
78	-03:-02	-11:-21	0.63	--	1.30	--	0.85
79	03:07	-09:-11	0.50	--	1.05	--	0.75
80	05:05	-06:-11	--	--	--	--	--
81	10:07	-03:-07	0.45	--	0.75	0.60	0.63
82	09:-01	-05:-03	0.44	0.45	1.06	0.75	0.68
83	00:01	-05:-07	0.60	0.48	1.18	0.75	0.76
84	03:09	-10:-14	0.45	0.52	0.85	0.66	0.71
85	07:12	-06:-08	0.43	0.28	0.64	--	0.57
86	08:03	-02:-03	--	0.46	0.66	0.61	0.61
87	02:06	-05:-11	--	--	--	--	--
88	07:03	-02:-05	0.60	--	0.80	0.83	0.56
89	00:00	-06:-12	0.60	0.81	0.98	0.70	0.83
90	-05:-06	-10:-09	0.60	0.64	0.98	0.71	0.83
91	-08:-05	-14:-17	0.75	0.63	1.33	0.73	1.15
92	-13:-08	-19:-16	0.66	1.05	1.57	0.84	0.98
93	-12:-10	-17:-12	0.80	1.31	1.51	1.15	1.33

From the data in Table 3 one can see that the Livingstone residence frequently experienced the lowest rate of temperature decay. This is likely a result of homeowner attention to retrofit details including increased insulation levels (RSI 10) in the attic, well sealed doors and windows, and an isolated furnace room. The Hall residence and Kananaskis 5A experienced variable decay rates, attributable to occupant lifestyle. The Edgemont Home had a fairly high but consistent decay rate. The Cairns Home, an energy efficient design, constantly experienced the most extreme rate of heat decay.

The higher temperature decay rates in the energy conserving houses may be attributed to the lack of occupancy-related inputs such as electricity use during furnace shutdown. However, since the setback period commenced late in the evening when most occupants were inactive, this free heat input may be quite low, even in the occupied houses.

To further evaluate the performance of the houses, the records collected from the furnace monitoring instruments were abstracted and analyzed for fuel consumption and heating system performance. These analyses are described in the following section.

Furnace Cycles per Day

To facilitate data reduction and subsequent analysis, strip chart records of furnace cycling for each day of the study were arranged in twenty four hour intervals from 0200 - 0200 to encompass maximum and minimum daily temperatures. The originals of the furnace cycling records have been submitted to the client. The number of furnace cycles and length of furnace on-time were abstracted from these records. The range of furnace cycles per day is summarized in Table 4.

Table 4 Furnace Cycles per Day

DAY 1982	LVN	HAL	CAR	KNA	EDG
68	43	20	6	36	89
69	35	5	5	27	97
70	57	4	7	27	98
71	50	3	7	32	95
72	40	0	6	22	97
73	41	5	6	30	94
74	51	147	6	26	88
75	62	142	6	35	80
76	73	222	5	35	70
77	80	253	7	37	77
78	127	280	6	37	68
79	50	237	6	35	88
80	26	237	6	22	96
81	31	112	5	24	97
82	34	94	6	20	91
83	35	100	7	29	96
84	51	102	6	25	89
85	33	56	6	19	96
86	23	24	5	14	100
87	70	112	5	21	87
88	48	60	8	18	49
89	9	7	6	16	7
90	9	26	6	27	7
91	6	18	6	23	8
92	14	26	6	21	6
93	18	31	5	27	7
94	14	34	5	30	6
95			5	22	6

A plot of these data is illustrated on the following page in Figure 7.

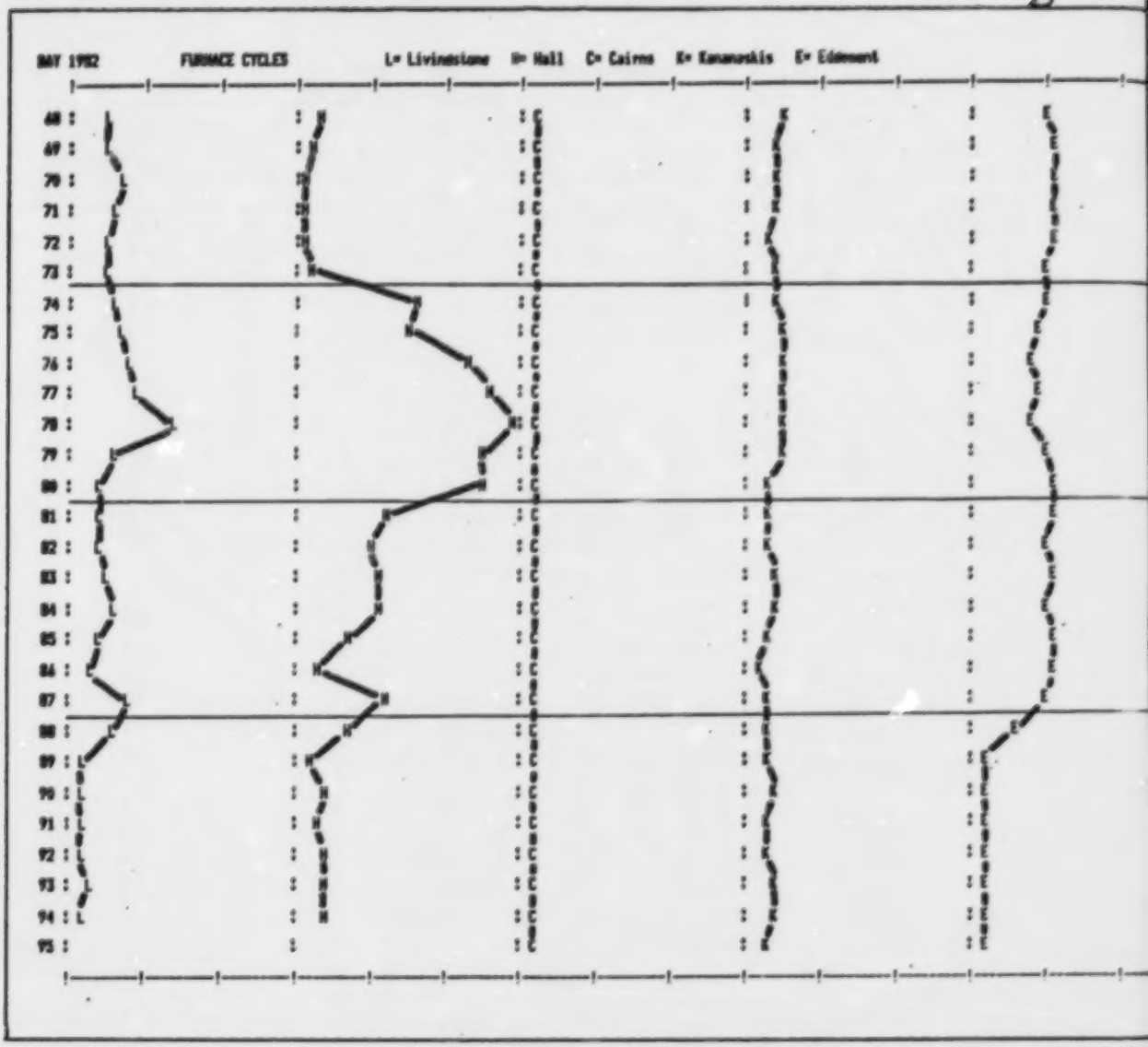


Figure 7

A plot of furnace cycles per day (FC/D) for the houses studied. The houses are plotted on individual scales of 0 - 300 FC/D. The study period includes day 68 through day 95, 1982 (09 March through 05 April).

The plot of furnace cycles illustrates the significant changes in test conditions during the study. In particular, the data for the Hall residence show the effect of the defective thermostat in the first week; the original thermostat during the second week; a setback thermostat adjusted to the initial anticipator setpoint during the third week; and the fourth week with the anticipator set to 1. The decreased number of furnace cycles during the third week is attributed to the operation of the setback thermostat. The condition of rapid furnace cycling did not change.

For the other houses tested, the only significant change occurs in week four, where the effect of the anticipator adjustment can also be seen in the Livingstone and Edgemont houses.

Furnace Cycles per Degree Day

To better visualize the operation of the furnaces, it is helpful to normalize the data for the effect of changes in the outside temperature during the test period.

Meteorological data were obtained from Atmospheric Environment Service (AES) Climatological Stations at Calgary International Airport and the Kananaskis Centre Field Station. Tables 5 and 6 summarize the climatic data for the study period in March and April 1982. Maximum and minimum temperatures for each 24 hour day, heating degree days, average wind speed in kilometers per hour, and total hours of bright sunshine are tabulated. Maximum and minimum daily temperatures have been transferred to the inside temperature thermograph records of the houses included in Appendix B.

Consistent with AES methodology, the heating degree days have been calculated as the differential between a base temperature of 18 deg C and the average of the maximum and minimum temperatures for each day.

MONTHLY METEOROLOGICAL SUMMARY March 1982

	Calgary Alberta 51 N 114 W 1080 M Intl. Airport					Kananaskis Alberta 51 N 115 W 1400 M U of C Field Station				
Day # mo/yr	Temp. deg.C Max	Min	Degree Days	Wind km/h	Sun Hours	Temp. deg.C Max	Min	Degree Days	Wind km/h	Sun Hours
01 60	-11.6	-19.6	33.6	29	0.0	-14.5	-18.0	34.5	07	0.2
02 61	-15.0	-21.0	36.0	19	5.9	-11.5	-23.5	35.5	03	7.4
03 62	-14.6	-22.2	36.4	17	4.5	-11.0	-22.5	34.5	03	1.5
04 63	-11.2	-18.6	32.9	09	6.7	-06.5	-17.5	30.0	05	7.3
05 64	03.2	-17.5	25.2	23	9.6	03.5	-19.0	25.8	09	7.0
06 65	01.0	-15.7	25.4	13	7.9	03.5	-17.5	25.0	09	7.0
07 66	-00.8	-16.3	26.6	23	2.5	03.0	-14.0	23.5	06	2.0
08 67	02.7	-15.6	24.5	21	7.6	05.0	-10.5	20.8	16	5.3
09 68	07.4	-03.0	15.8	26	5.1	07.0	01.0	14.0	11	4.0
10 69	04.0	-08.9	20.5	17	4.6	04.5	-09.0	20.2	14	6.2
11 70	07.5	-06.4	17.4	44	5.7	04.5	-06.0	18.8	10	5.0
12 71	02.6	-09.3	21.4	40	9.4	-01.0	-07.5	22.2	10	5.9
13 72	04.7	-06.6	19.0	16	7.2	01.5	-09.0	21.7	04	0.0
14 73	00.5	-07.1	21.3	22	4.7	-01.5	-08.5	23.0	01	0.0
15 74	00.2	-05.5	20.7	17	4.7	-01.0	-07.5	22.5	02	3.0
16 75	-01.3	-07.1	22.2	19	1.1	-03.0	-11.0	25.0	03	1.0
17 76	-04.3	-12.7	26.5	32	0.0	-05.5	-08.5	25.0	04	1.0
18 77	-06.6	-18.8	30.4	14	7.4	-05.5	-22.0	31.7	04	2.6
19 78	-03.0	-11.4	25.2	14	0.0	02.5	-21.0	27.2	03	4.6
20 79	03.2	-09.1	21.0	17	7.7	07.0	-11.0	20.0	04	8.4
21 80	04.9	-06.7	18.9	13	7.6	05.5	-11.0	20.8	09	9.1
22 81	09.6	-03.5	14.9	32	8.0	07.0	-08.0	18.5	18	9.7
23 82	09.0	-05.5	20.3	22	9.2	-01.5	-03.5	20.5	02	0.0
24 83	00.1	-05.8	20.9	24	8.9	01.5	-07.5	21.0	04	7.8
25 84	03.4	-10.0	21.3	22	9.2	09.0	-14.0	20.5	07	6.8
26 85	06.8	-05.9	17.5	31	9.7	12.0	-08.0	16.0	10	10.2
27 86	07.8	-02.5	15.3	24	10.0	03.5	-03.0	17.8	08	3.5
28 87	01.8	-05.0	19.6	23	0.0	06.0	-11.0	20.5	07	8.7
29 88	07.4	-02.0	15.3	35	7.1	03.5	-05.5	19.0	09	9.2
30 89	00.5	-06.2	20.9	27	3.6	00.0	-12.0	24.0	05	3.1
31 90	-04.9	-09.8	25.4	35	0.0	-06.5	-09.0	25.8	05	0.0

Table 5

Climatic data from Calgary International Airport and the University of Calgary: Kananaskis Field Station for March 1982. The columns under "Day #" correspond to monthly day numbers and yearly day numbers as measured from Jan. 01. Yearly day numbers are used throughout the study to describe the monitoring period.

MONTHLY METEOROLOGICAL SUMMARY April 1982

	Calgary Alberta 51 N 114 W 1080 M Intl. Airport					Kananaskis Alberta 51 N 115 W 1400 M U of C Field Station				
Day # mo/yr	Temp. deg.C Max	Min	Degree Days	Wind km/h	Sun Hours	Temp. deg.C Max	Min	Degree Days	Wind km/h	Sun Hours
01 91	-07.6	-14.1	28.9	35	5.1	-05.5	-17.0	29.2	07	3.9
02 92	-12.6	-18.7	33.7	19	3.0	-08.5	-16.0	30.2	07	1.7
03 93	-12.1	-17.0	32.6	35	1.2	-10.5	-12.0	32.2	04	1.8
04 94	-08.9	-17.0	31.0	27	5.3	-05.0	-25.5	33.2	05	7.4
05 95	-05.4	-15.1	28.3	20	1.0	-00.5	-19.5	28.0	04	3.3
06 96	-06.3	-11.6	27.0	22	5.9	-05.5	-17.5	29.5	04	0.3
07 97	-03.8	-18.5	29.2	15	9.7	-00.5	-21.5	29.0	07	10.4
08 98	04.9	-09.5	20.3	40	0.9	03.5	-11.5	22.0	13	1.3
09 99	04.9	-08.6	19.9	29	8.7	05.5	-14.0	22.2	15	6.4
10 100	11.5	-01.4	12.9	22	8.8	07.5	00.5	14.0	18	7.3
11 101	04.5	-02.7	17.1	23	4.7	04.0	-00.5	16.2	05	1.3
12 102	12.7	-00.4	11.8	21	2.9	09.5	-05.0	15.8	12	4.3
13 103	13.7	-00.3	11.3	31	11.2	08.5	-01.5	14.5	11	4.1
14 104	06.4	-01.8	15.7	32	12.4	01.0	-04.5	19.8	13	1.7
15 105	06.7	-02.3	15.8	36	7.2	04.0	-09.5	20.8	18	8.8
16 106	09.3	-03.5	15.1	33	13.5	03.5	-02.0	17.2	20	9.9
17 107	11.6	-02.4	13.4	24	12.7	05.5	-01.0	15.8	13	9.7
18 108	05.6	-03.5	16.9	47	6.5	01.0	-05.0	20.0	11	4.6

Table 6 Climatic data from Calgary International Airport and the University of Calgary: Kananaskis Field Station for the study period in April 1982.

A linear regression analysis of the Calgary degree days with the Kananaskis degree days for the test period shows a correlation coefficient (R) of 0.94, thus comparisons between Calgary and Kananaskis houses during the study are valid. Plots of the regression analyses are included in Appendix C.

To normalize the furnace cycles per day for heating load as a function of outside temperature, the furnace cycles were divided by the heating degree days for each day of the study. This parameter is summarized below in Table 7.

Table 7 Furnace Cycles per Degree Day

DAY 1982	LVN	HAL	CAR	KNA	EDG
68	2.72	1.27	0.38	2.57	5.63
69	1.71	0.24	0.24	1.34	4.73
70	3.28	0.23	0.40	1.44	5.63
71	2.34	0.14	0.33	1.44	4.44
72	2.11	0.00	0.32	1.01	5.11
73	1.92	0.23	0.28	1.30	4.41
74	2.46	7.10	0.29	1.16	4.25
75	2.79	6.40	0.27	1.40	3.60
76	2.75	8.38	0.19	1.40	2.64
77	2.63	8.32	0.23	1.17	2.53
78	5.04	11.11	0.24	1.36	2.70
79	2.38	11.29	0.29	1.75	4.19
80	1.38	12.54	0.32	1.06	5.08
81	2.08	7.52	0.34	1.30	6.51
82	1.67	4.63	0.30	0.98	4.48
83	1.67	4.78	0.33	1.38	4.59
84	2.39	4.79	0.28	1.22	4.18
85	1.89	3.20	0.34	1.19	5.49
86	1.50	1.57	0.33	0.79	6.54
87	3.57	5.71	0.26	1.02	4.44
88	3.14	3.92	0.52	0.95	3.20
89	0.43	0.33	0.29	0.67	0.33
90	0.35	1.02	0.24	1.05	0.28
91	0.21	0.62	0.21	0.79	0.28
92	0.42	0.77	0.18	0.70	0.18
93	0.55	0.95	0.15	0.84	0.21
94	0.45	1.10	0.16	0.90	0.19
95			0.18	0.79	0.21

A plot of these data is illustrated on the following page in Figure 8.

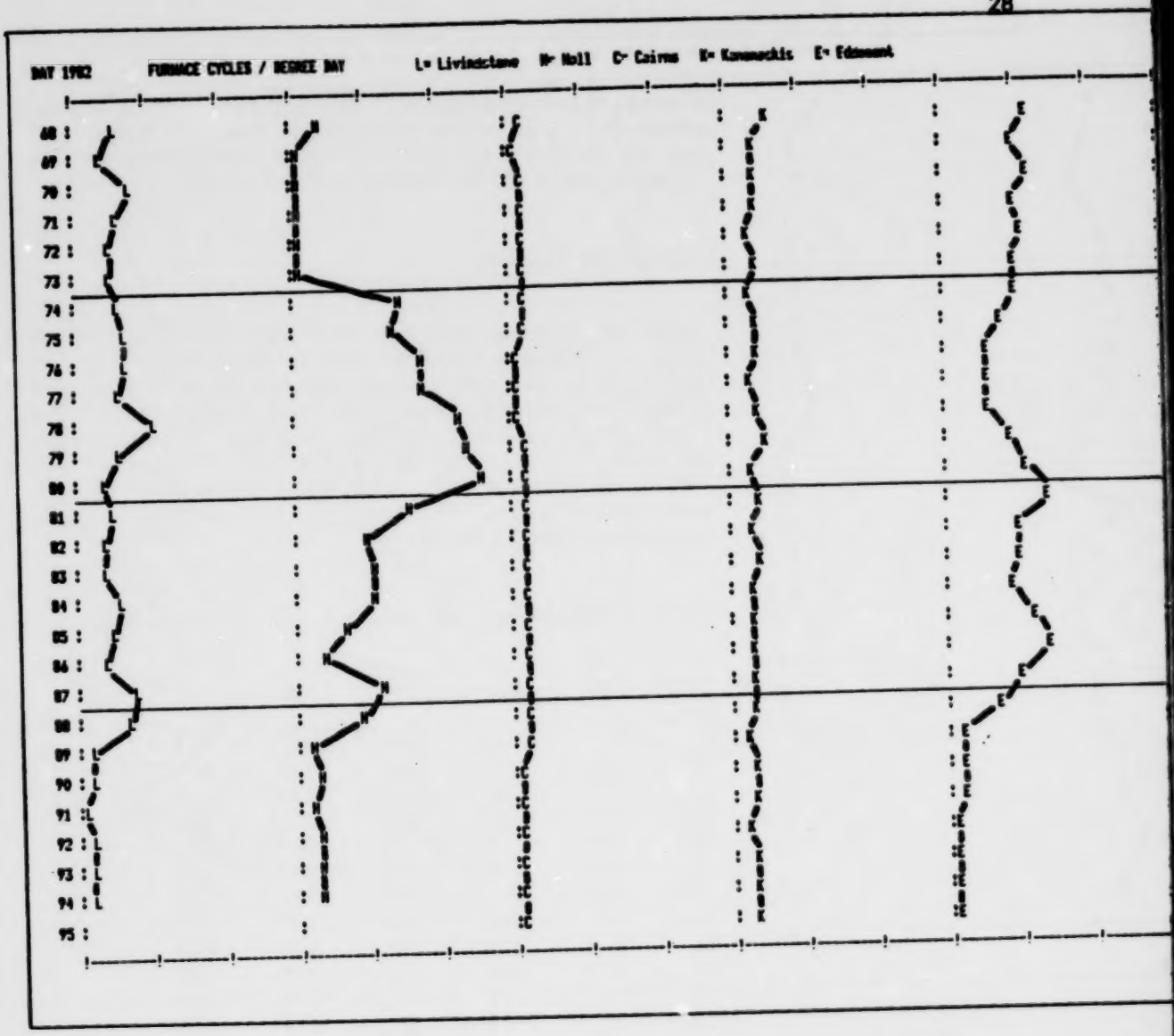


Figure 8

A plot of furnace cycles per degree day (FC/DD) for the houses studied. The houses are plotted on individual scales of 0 - 15 FC/DD.

A comparison of figures 7 and 8 shows little change other than a shift in the peak of the Hall data from day 80 to day 78, and a greater variation in the Edgemont data during weeks two and three.

Megajoules per Day

Hours of furnace burn for each day were abstracted from the furnace recorder charts by integrating the duration of the individual 'on' cycles. To enable a comparison among houses for fuel consumption, the calibration constant for each furnace in megajoules per hour was multiplied by the total hours of gas valve on-time, for each day. These data are summarized below in Table 8, and plotted on the following page in Figure 9.

Table 8 Megajoules per Day

DAY 1982	LVN	HAL	CAR	KNA	EDG
68	227	44	456	389	600
69	185	5	456	271	568
70	288	22	520	284	552
71	257	22	528	323	504
72	216	0	472	244	584
73	278	4	528	257	616
74	299	555	560	284	632
75	371	566	568	297	688
76	412	610	664	290	680
77	453	699	704	317	624
78	587	777	656	330	664
79	257	655	520	317	536
80	144	655	392	185	520
81	195	322	344	218	448
82	175	344	464	205	712
83	175	422	448	264	552
84	330	377	456	251	624
85	185	200	368	238	512
86	113	107	240	165	504
87	330	477	408	191	616
88	268	255	352	205	576
89	237	300	456	231	552
90	350	411	552	330	656
91	206	500	544	224	640
92	494	433	648	231	672
93	515	566	704	297	744
94	484	744	664	370	672
95			576	224	624

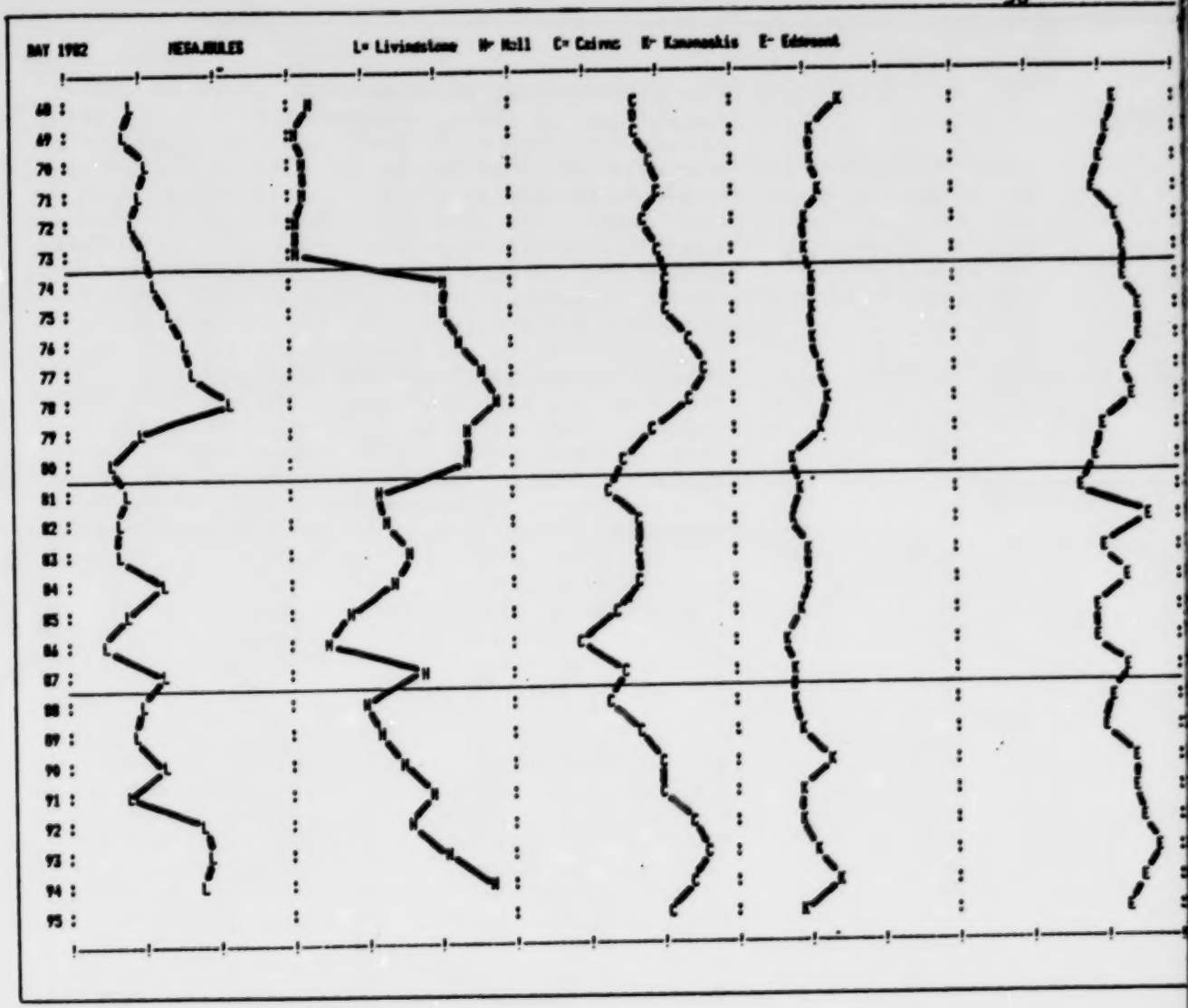


Figure 9

A plot of megajoules per day (MJ/D) for the houses studied. The houses are plotted on individual scales of 0 to 800 MJ/D.

The plot of megajoules per day gives an overall comparison of energy requirements for the study houses. The Edgemont house uses consistently more fuel than the other houses while the Cairns and Hall houses used nearly as much, and sometimes more at peak usage. The Livingstone and Kananaskis houses used less fuel than the others. The greater irregularity of fuel use in the Livingstone and Hall houses is probably due to the greater amount of occupant activity. It is significant that the unoccupied Cairns and Edgemont houses, new "energy conserving designs", did not use substantially less fuel than the well insulated 1950's and 1960's study houses. This was probably due to the absence of internal heat gains which occur during normal occupancy. The thermostats in these two houses were programmed with temperature schedules which approximated typical occupant set back schedules.

The number of megajoules per day represents the "bottom line" in terms of comparative house performance, since it can be translated to dollars per day for the homeowner.

All of the houses showed varying increases in megajoules per day when the anticipator setting was increased to 1. However, from the data plots it is difficult to ascertain whether this increase during week four is attributable to house size, change in climatic conditions, change in interior temperature, other occupancy factors, or furnace cycling rate.

Additional computations were performed with the megajoules per day data to normalize for the different sizes of the study houses and the variability of climate. The results of these computations are presented in the following tables and plots. These offer a graphic comparison among the houses to assess the effects of the different operating conditions of the furnaces.

Megajoules per Volume

To provide a basis for comparison among the houses, it is useful to divide the megajoules per day by the volume of the house in cubic metres. This was calculated as input to the heat loss analysis. The megajoules per volume data can be compared among the houses to note the different responses of the houses to similar weather conditions.

Table 9 Megajoules per Volume

DAY 1982	LIV	HAL	CAR	KNA	EDG
68	0.51	0.09	0.74	1.35	0.86
69	0.42	0.01	0.74	0.94	0.82
70	0.65	0.04	0.84	0.99	0.80
71	0.58	0.04	0.85	1.12	0.73
72	0.49	0	0.76	0.85	0.84
73	0.63	0.01	0.85	0.89	0.89
74	0.68	1.11	0.91	0.99	0.91
75	0.84	1.13	0.92	1.03	0.99
76	0.93	1.22	1.07	1.01	0.98
77	1.03	1.40	1.14	1.10	0.90
78	1.33	1.55	1.06	1.15	0.96
79	0.58	1.31	0.84	1.10	0.77
80	0.33	1.31	0.63	0.64	0.75
81	0.44	0.64	0.56	0.76	0.65
82	0.40	0.69	0.75	0.71	1.03
83	0.40	0.84	0.72	0.92	0.80
84	0.75	0.75	0.74	0.87	0.90
85	0.42	0.40	0.60	0.83	0.74
86	0.26	0.21	0.39	0.57	0.73
87	0.75	0.95	0.66	0.66	0.89
88	0.61	0.51	0.57	0.71	0.83
89	0.54	0.60	0.74	0.80	0.80
90	0.79	0.82	0.89	1.15	0.95
91	0.47	1.00	0.88	0.78	0.92
92	1.12	0.87	1.05	0.80	0.97
93	1.17	1.13	1.14	1.03	1.07
94	1.10	1.49	1.07	1.28	0.97
95			0.93	0.78	0.90

A plot of these data is illustrated on the following page in Figure 10.

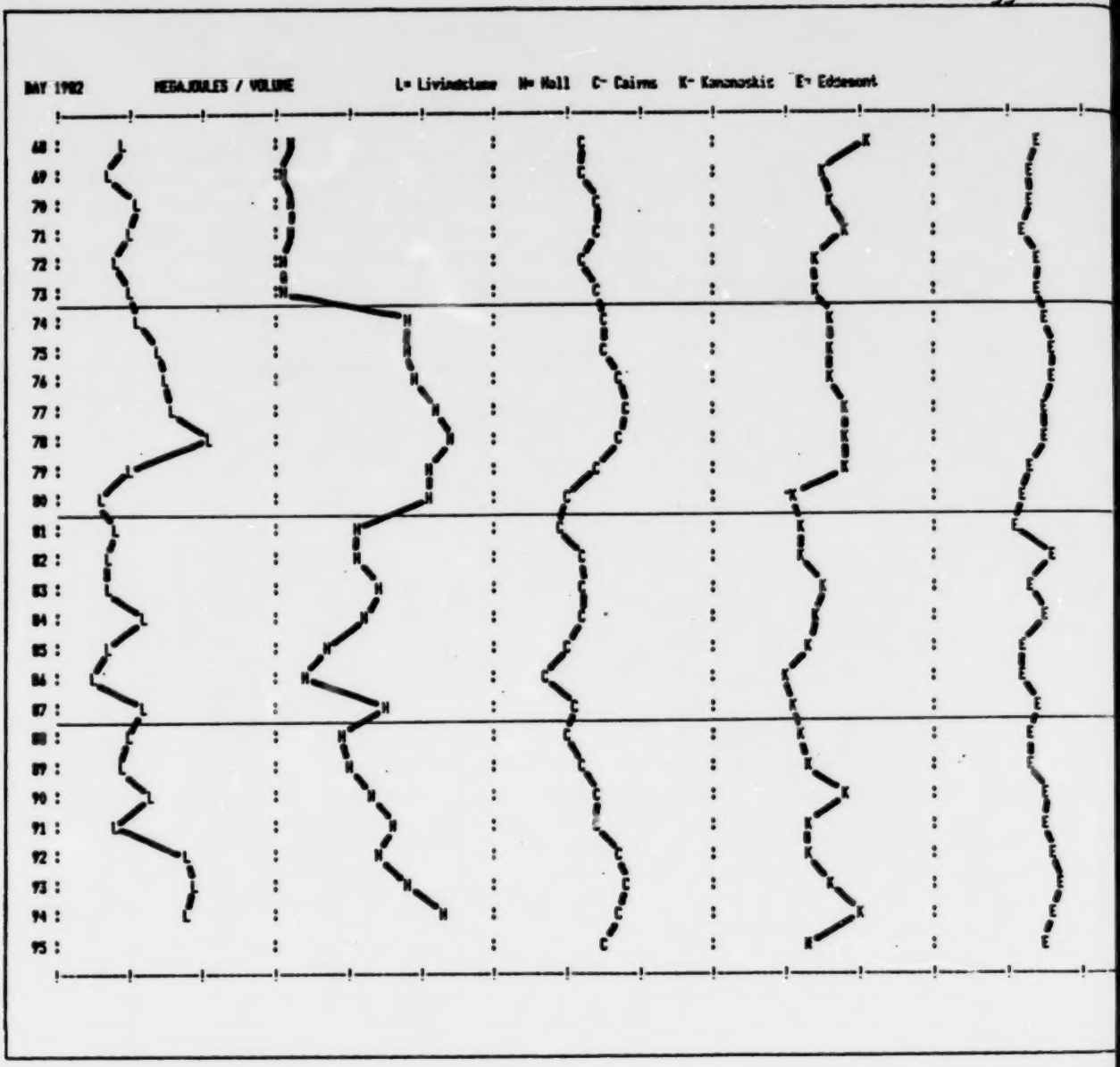


Figure 10

A plot of megajoules per volume (MJ/m3) for the houses studied. The houses are plotted on individual scales of 0 to 2 MJ/m3.

Figure 10 illustrates the relative response of the houses, normalized for differences in size, to changes in the climate and occupancy related factors. The Livingstone, Hall, and Cairns houses show the effect of increasingly cold weather on days 75 through 78. As well, the response of the houses to warmer weather and increased sunshine on days 84 through 86 is evident. Since week four was increasingly colder, it is difficult to assess the effect of fewer furnace cycles.

Megajoules per Degree Day

To normalize the data for variable climate during the study period, the daily megajoules were divided by the degree days. These results are shown below in Table 10, and on the following page in Figure 11.

Table 10 Megajoules per Degree Day

DAY 1982	LVN	HAL	CAR	KNA	EDG
68	14.34	2.81	28.86	27.81	37.97
69	9.04	0.27	22.24	13.40	27.71
70	16.57	1.28	29.89	15.10	31.72
71	12.03	1.04	24.67	14.57	23.55
72	11.38	0	24.84	11.25	30.74
73	13.06	0.21	24.79	11.19	28.92
74	14.43	26.81	27.05	12.61	30.53
75	16.70	25.50	25.59	11.88	30.99
76	15.55	23.04	25.06	11.62	25.66
77	14.91	23.00	23.16	9.99	20.53
78	23.30	30.83	26.03	12.13	26.35
79	12.26	31.19	24.76	15.84	25.52
80	7.63	34.65	20.74	8.88	27.51
81	13.13	21.60	23.09	11.77	30.07
82	8.63	16.95	22.86	9.98	35.07
83	8.38	20.18	21.44	12.57	26.41
84	15.47	17.72	21.41	12.23	29.30
85	10.59	11.42	21.03	14.85	29.26
86	7.41	6.96	15.69	9.27	32.94
87	16.82	24.35	20.82	9.34	31.43
88	17.50	16.69	23.01	10.77	37.65
89	11.33	14.34	21.82	9.63	26.41
90	13.79	16.17	21.73	12.79	25.83
91	7.13	17.28	18.82	7.68	22.15
92	14.67	12.85	19.23	7.65	19.94
93	15.80	17.37	21.60	9.22	22.82
94	15.62	23.99	21.42	11.13	21.68
95			20.35	8.01	22.05

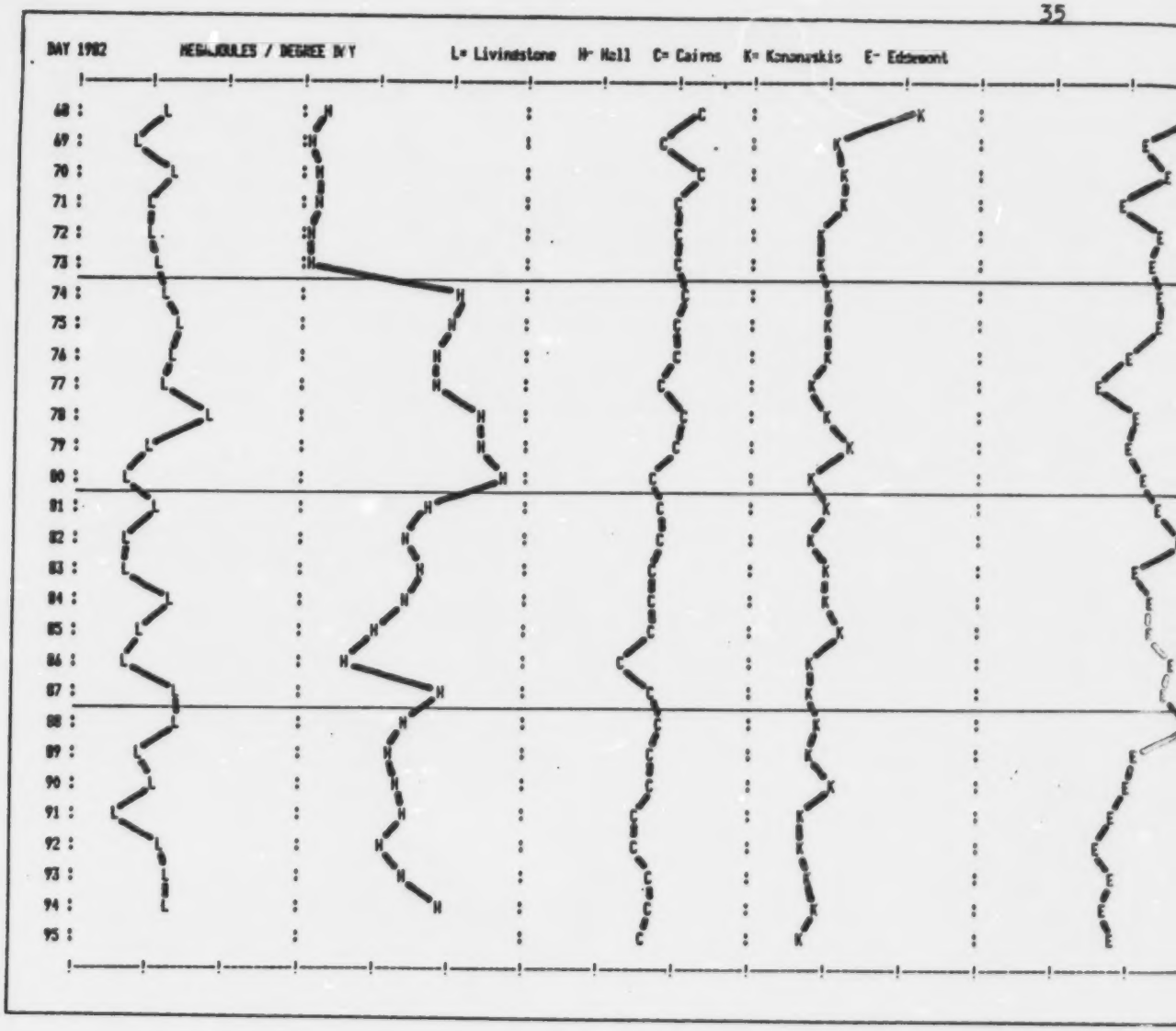


Figure 11

A plot of megajoules per degree day (MJ/DD) for the houses studied. The houses are plotted on individual scales of 0 to 40 MJ/DD.

The plot of megajoules per degree day clearly shows the effects of occupancy and furnace performance for the individual houses throughout the study period. In particular, the effects of the anticipator adjustment in week four can be most clearly seen in the Edgemont house. Figure 11 shows a decrease in megajoules per degree day from an average of 31.72 MJ/DAY in Week 3 to an average of 22.98 MJ/DAY in Week 4. The occupied houses show as much variation as before with no significant change.

Megajoules per Volume per Degree Day

To compare the houses with reference to a measurable performance criteria, one can divide the megajoules per volume data by degree days. The results of this calculation are summarized in Table 11 below, and illustrated on the following page in Figure 12.

Table 11 Megajoules per Volume per Degree Day

DAY 1982	LVN	HAL	CAR	KNA	EDG
68	0.0323	0.0057	0.0468	0.0964	0.0544
69	0.0205	0.0005	0.0361	0.0465	0.0400
70	0.0374	0.0023	0.0483	0.0527	0.0460
71	0.0271	0.0019	0.0397	0.0505	0.0341
72	0.0258	0.0000	0.0400	0.0392	0.0442
73	0.0296	0.0005	0.0399	0.0387	0.0418
74	0.0329	0.0536	0.0440	0.0440	0.0440
75	0.0378	0.0509	0.0414	0.0412	0.0446
76	0.0351	0.0460	0.0404	0.0404	0.0370
77	0.0339	0.0461	0.0375	0.0347	0.0296
78	0.0528	0.0615	0.0421	0.0423	0.0381
79	0.0276	0.0624	0.0400	0.0550	0.0367
80	0.0175	0.0693	0.0333	0.0308	0.0397
81	0.0295	0.0430	0.0376	0.0411	0.0436
82	0.0197	0.0340	0.0369	0.0346	0.0507
83	0.0191	0.0402	0.0344	0.0438	0.0383
84	0.0352	0.0352	0.0347	0.0424	0.0423
85	0.0240	0.0229	0.0343	0.0519	0.0423
86	0.0170	0.0137	0.0255	0.0320	0.0477
87	0.0383	0.0485	0.0337	0.0322	0.0454
88	0.0399	0.0333	0.0373	0.0374	0.0542
89	0.0258	0.0287	0.0354	0.0333	0.0383
90	0.0311	0.0323	0.0350	0.0446	0.0374
91	0.0163	0.0346	0.0304	0.0267	0.0318
92	0.0332	0.0258	0.0312	0.0265	0.0288
93	0.0359	0.0347	0.0350	0.0320	0.0328
94	0.0355	0.0481	0.0345	0.0386	0.0313
95			0.0329	0.0279	0.0318

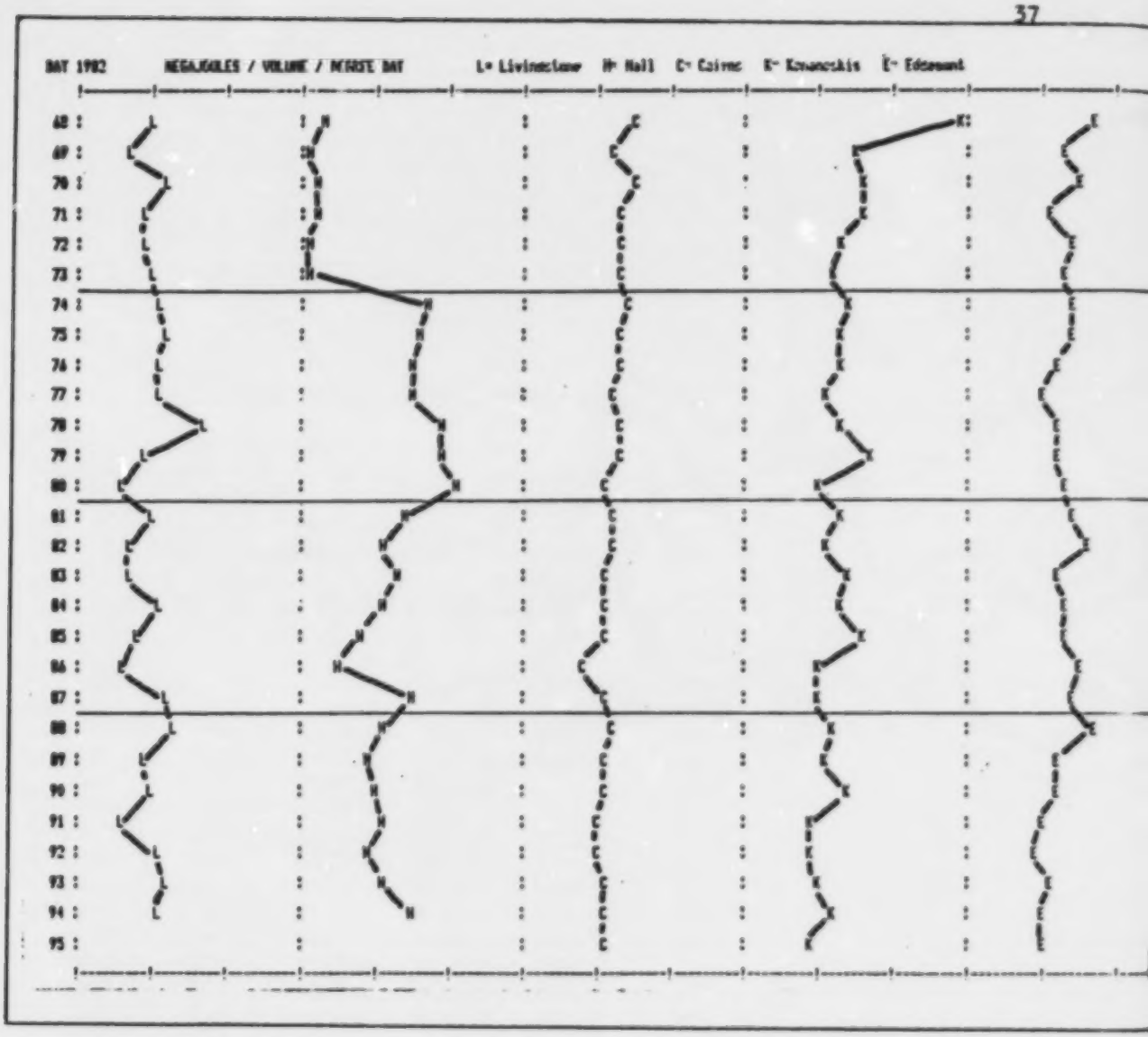


Figure 12

A plot of megajoules per volume per degree day (MJ/m3/DD) for the houses studied. The houses are plotted on individual scales of 0 to 0.1 MJ/m3/DD.

The plot of megajoules per volume per degree day (Figure 12) provides a means of comparing the performance of the study houses during the test period. The stability of the unoccupied Cairns house as a basis of comparison is particularly evident. This house appears to be operating at near optimum for the climatic conditions and short intervals of occupancy during the study. Changing the thermostat anticipator setting did not measurably change the performance of the house or the number of furnace cycles per day.

The plot of the Kananaskis house shows some variability throughout the test period. Other than the significant decrease on day 69 when the furnace fan was switched to continous operation, the performance varies about a mean which is very similar to the performance of the Cairns house. There is a slight decrease in the average performance between day 69 and day 95; there is also a similar decrease in the furnace cycles per degree day plot in Figure 8. This slight decrease in megajoules per volume per degree day is also evident in the Cairns house. This effect may be related to increasing day length and a slight increase in average daily solar radiation. Because the thermostat anticipator in the Kananaskis house had been set to 1 before the study began, the variability in performance can be attributed to occupant activity.

The plot of the Livingstone house indicates a fairly consistent average performance, with an extent of variability which is likely caused by occupant activity. As noted above, adjusting the anticipator to 1 did not significantly change the duration of the furnace burner cycle. Increasing the gas valve limit switch from a setpoint of 43.3 C to 93.3 C (110 F to 200 F) significantly increased the duration of the cycle, however no significant change in the average performance is evident from the plot of megajoules per volume per degree day.

The plot of the Hall house clearly shows the relative effects of the inoperative thermostat, the original thermostat, and the set back thermostat as discussed above. The performance significantly changes from week-to-week during the first three weeks of the study. This method of measuring the performance of a residential heating system indicates conditions of 'very efficient' operation in the Hall house during the first week of the study.

The occupants, however, found that this very effective method of energy conservation was somewhat less than desirable in terms of comfort. We especially wish to thank them for their patience during the initial period of the study.

While the adjustment of the anticipator significantly reduced the number of furnace cycles per day in the Hall house, the average performance did not appear to change between weeks three and four. It was noted during the regular visits to this house, that one window was continuously open, and that doors and windows were frequently open on sunny days and during periods of substantial visitor activity. Since approximately one quarter of the basement is used as an office space, a highly variable activity pattern occurs throughout the day, this probably accounts for most of the variation in relative performance for this house. These varying conditions of occupancy remained consistent throughout the study period.

The occupants did note that warm temperatures were more evenly distributed throughout the house, particularly in the basement, during week four. As well, they noted that the house came up to the daytime operating temperature more quickly than before. The thermograph records in Appendix B also show the more rapid temperature rise in the morning. The increase in fuel requirement from day 92 to day 94, at the end of the study, may be a function of the improved temperature distribution throughout the house and the occupants becoming familiar with the different operating conditions of the furnace.

The plot of megajoules per volume per degree day for the Edgemont house shows no significant change in average performance during the first three weeks of the test period. It is unusual, however, that the day-to-day performance varies nearly as much as the performance of the occupied houses. Of the houses studied, the Edgemont house exhibits both the greatest percent oversize and the most significant response to reduction in furnace cycles by anticipator adjustment. Not only did the relative fuel requirement decrease in week four, but the average inside temperature also increased. This was the only house in the study which exhibited a condition of temperature overshoot when the anticipator was adjusted. On the following page, a plot of MJ/m3/DD shows the means and standard deviations of the inside temperatures of the houses.

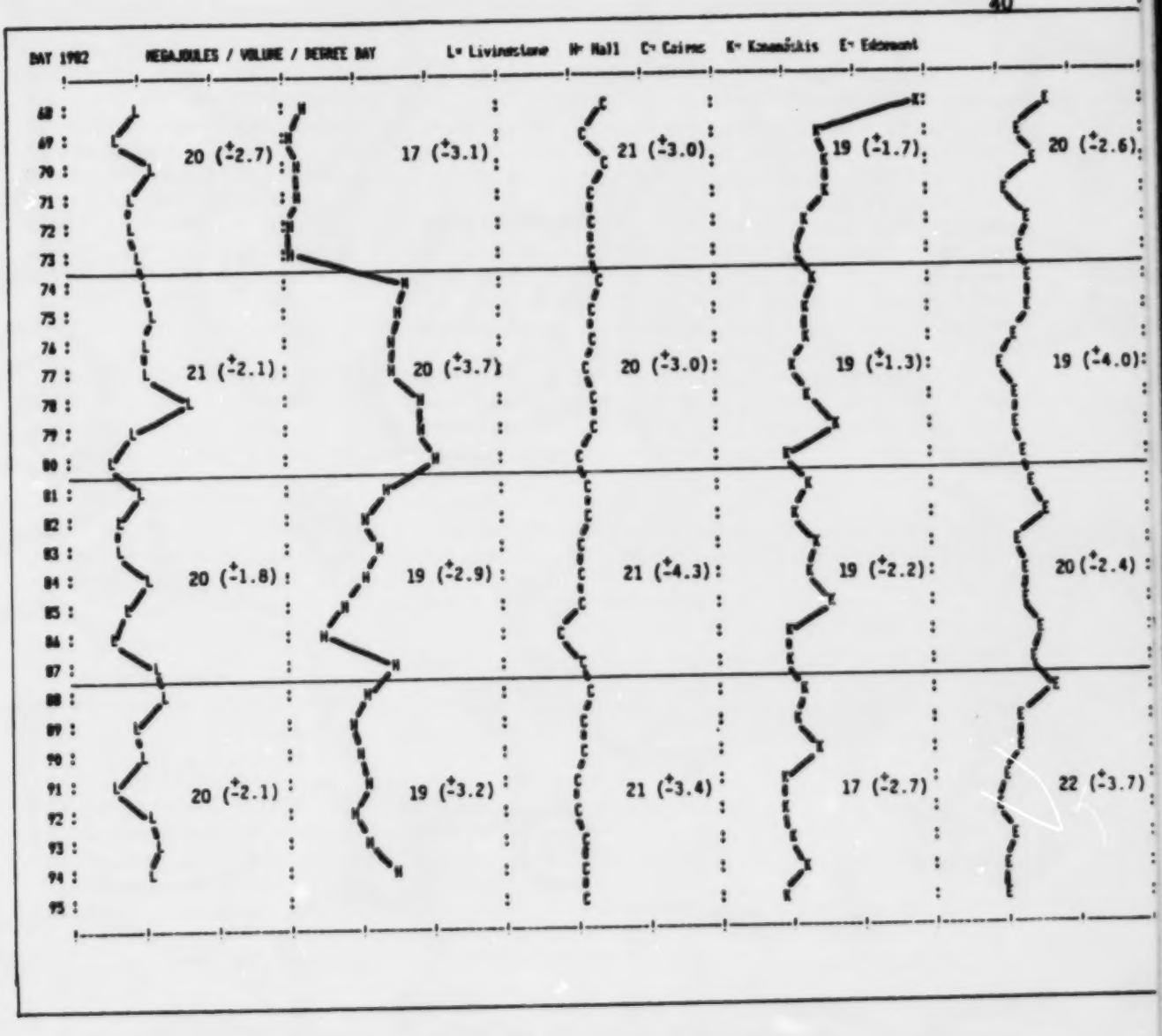


Figure 13

A plot of megajoules per volume per degree day for the houses studied. The weekly means and standard deviations of the inside temperatures in degrees Celsius have been added to the data plots.

The addition of the weekly means and standard deviations of the inside temperatures to the plots of megajoules per volume per degree day shows that with the exception of the Edgemont house, the average inside temperature of the houses did not increase significantly. This inside temperature was measured by a thermograph, centrally located on the main floor of each house. As noted above, the improved distribution of warmer temperatures in the Hall house did increase the comfort level in the house as perceived by the occupants.

The increase of average temperature in the Edgemont house during week four can be attributed to the change in anticipator setting since the temperature setpoints of the thermostat were taped in place to prevent any variation during the test period. This increase in temperature, in conjunction with the indicated reduction in megajoules per volume per degree day, shows that if actual degree days were used for the calculation, the indicated performance would be further improved.

Between 10 April and 18 April, the temperature and furnace recording instrumentation was installed in three of the ten houses at Kananaskis. For this test, all thermostat anticipators were set to 0.45 (the furnace manufacturers specification) to further determine the effect of anticipator setting on the performance of the heating system in the houses. It is interesting to note that this setting caused the furnace in the study house, Kananaskis 5A, to exhibit conditions of short cycling. The recorder charts for this reference-house test period are included with the recorder charts for the study period.

The study house data for furnace cycles, megajoules, and megajoules per volume, were plotted against degree days in a scattergram--linear regression analysis to examine another method of graphically evaluating heating system performance. The plots of megajoules per volume versus degree days are particularly useful for showing the range of furnace performance criteria. Those data points which plot in the upper left area of the scattergram (fewer megajoules per volume with greater degree days) are evidence of conditions of increased furnace performance, if it can be assumed that adequate levels of occupant comfort were met. These plots are included in Appendix C.

From the data on megajoules per degree day, it will be noted that the houses show relatively little change in fuel consumption per degree day after the adjustment to the anticipator setting. The largest change occurs in the Edgemont house, where the furnace 'on' time per cycle was increased by a factor of about 13.5. This produced a reduction in MJ/DD of about 21%, indicating a possible improvement in the seasonal efficiency. However, the Kananaskis house showed a parallel reduction in MJ/DD of about 18%, achieved without any change in the anticipator setting. It can therefore be concluded that if any improvement in seasonal efficiency was produced as a result of changes in the anticipator setting, the effect was too small to be isolated from other uncontrolled effects.

Table 12 gives a general summary of of data relating to the effects of furnace oversizing and anticipator setting.

The furnace performances, before and after adjustment of the anticipator setting on day 88, should give an indication of the effect of anticipator setting. The analysis has been concentrated on two periods: the first is a two-week period from day 74 to day 88, during which most of the furnaces were operating in a relatively undisturbed condition at their original anticipator settings. The second period includes the last week of the study (day 89 to day 94 or 95, depending on when the field work was terminated). In this second period all furnaces were operated with the anticipator set to 1.0.

The analysis concentrates on two factors. The first factor is the average megajoules per cycle, which is proportional to the average furnace 'on' time per cycle. The second factor is the average megajoules per degree day, before and after day 88, which gives a relative indication of the total operating efficiency of the furnace.

Table 12 Summary of Furnace Performance

	LVN	HAL	CAR	KNA	EDG
AVERAGES FOR PERIOD FROM DAY 74-88					
Anticipator setting:	0.35	0.35	0.70	1.00	0.35
Mean MJ/cycle :	5.48	3.51	80.3	9.73	7.28
MJ/DD :	13.9	22.6	23.0	11.5	28.7
Temperature decay (deg C/hour) :	0.51	0.68	1.02	0.70	0.73
AVERAGES FOR PERIOD FROM DAY 89-94/95					
Anticipator setting:	1.00	1.00	1.00	1.00	1.00
Mean MJ/cycle :	31.1	23.9	107.9	11.6	98.1
MJ/DD :	13.2	17.1	20.6	9.4	22.7
Temperature decay (deg C/hour) :	0.68	0.89	1.27	0.83	1.02
FURNACE EFFICIENCY ANALYSIS DAY 89 - DAY 94/95					
Total fuel consumed (MJ) :	2286	2954	4144	1907	4560
Mean Atm. Temp (C) :	-10.7	-10.7	-10.6	-10.9	-10.6
Calculated Heat Loss (MJ) :	6058	6294	4801	4296	3174
Consumption/ Heat loss :	0.38	0.47	0.86	0.44	1.44
(corrected) :			(0.73)		(1.25)
South Window Area (m2) :	1.39	8.25	15.60	1.80	14.30

In the Livingstone, Hall, and Edgemont houses, the furnace 'on' time per cycle was increased by a factor ranging from 6 to 14, when the anticipator setting was increased from 0.35 to 1.0. A change in setting from 0.7 to 1.0, on the Cairns house, increased the furnace 'on' time per cycle by a factor of 1.34. In the Kananaskis house the anticipator setting was 1.0 both before and after day 88. The data on this house show a change in 'on' time per cycle of about 19%. This gives an indication of the magnitude of other effects, such as changing climatic conditions and variations in occupancy patterns. From this analysis it can be concluded that the anticipator setting has a major effect on the 'on' time per cycle. Also, there are indications that furnace oversizing has a considerable effect on the sensitivity of the anticipator setting.

The following analysis of furnace oversizing effect from Table 12 has been confined to data taken after day 88, during which period all furnaces were operating with the same anticipator setting. The aim of the analysis was to compare the total fuel consumption with the calculated house heat loss for this period. The fuel consumption data are derived from Table 8. The heat loss is calculated from the heat loss coefficients given for each house in the Energy Design Analysis section of Appendix A. Above-grade heat loss is calculated with an assumed interior temperature of 22.5 C, and mean exterior temperature for this period of -10.6 C to -10.9 C. This information was derived from Table 5 and 6. Below-grade heat loss is calcuated using the design temperature difference used for the Design Analysis.

The exceptionally high ratio of fuel consumption to heat loss in the Cairns and Edgemont houses are due to two factors. First, these houses were unoccupied and therefore had no heat gains from occupancy; secondly, these two passive solar design houses have large south-facing window areas as shown in the Table. Part of the discrepancy may be due to limited passive solar performance during this period, which was characterized by cloudy conditions and an average of only 2.7 hours of direct sunlight per day. The fuel consumption for the two houses has been corrected by allowing an occupancy heat gain of 24 kWh per day. This reduces the fuel consumption/heat loss ratio to 0.73 and 1.25, but these figures are still excessively high compared with those for the other three houses.

The performance as measured by decay heat loss and fuel consumption in megajoules per degree day among the houses are generally comparable, with the Livingstone residence showing the best performance, and the Edgemont and Cairns Homes showing the poorest.

It is generally understood that as the furnace oversize factor is increased, the 'on' time per cycle is reduced and this results in a decrease in seasonal efficiency. The report shows that the setting of the anticipator can change the 'on' time per cycle by a considerable factor - possibly far greater than would occur through changes in the oversize factor. Large changes in the 'on' time per cycle, resulting from changes in the anticipator setting, have been shown to have a relatively small effect on the furnace performance, as expressed in megajoules per degree day. Therefore, it is reasonable to assume that the furnace oversizing factor would have an even smaller effect. This, however, is a highly theoretical assumption which would have to be verified by further research.

From this interpretation , there would appear to be a possibility of correcting the furnace oversizing effect by appropriate adjustment of the anticipator setting. This could also improve the reduction in seasonal efficiency due to furnace oversizing, however it might also create uncomfortable temperature variations in the house. Such a tendency is evident in the data presented in Figure 13. This effect also needs further research.

This pilot study has shown that the houses with furnaces which were oversized by more than 50%, exhibited conditions of short cycling when the thermostat anticipator was set to specifications provided by furnace manufacturers, or the setpoint noted in the original thermostat. When the anticipator was adjusted to eliminate the condition of short cycling, furnace performance improved in the case where the furnace was oversized by 133%. This indicates that the thermostat anticipator can have a significant effect on the performance of the heating system, particularly in the case where the furnace output exceeds the design temperature heating load by more than 50%.

It has also been noted by the authors and other researchers that the temperature setpoints of the furnace fan control significantly effect the performance of the heating system. For the purposes of this study the temperature controls in the study-house furnaces were bypassed with the manual fan switch. It is suggested that the interaction of the temperature setting of the thermostat, the anticipator setting, and the fan controls may contribute to reduced seasonal efficiency in furnaces, even if the oversize condition is less than 50%. The activities and comfort expectations of the occupants can also affect the seasonal efficiency of the house as a total heating system, when internal gains, solar gain, and ventilation rates are considered.

The study shows that the relationship between decay heat loss and energy system performance, as expressed in megajoules per degree day, is a complex interaction.

A far more detailed analysis would be necessary to isolate the furnace efficiency parameters from other conditions affecting building performance. In particular, a more detailed analysis on envelope heat loss, air exchange rates, occupancy gains and solar gains are required to establish more definitive conclusions. The last factor would require detailed monitoring of insolation. It was not the purpose of this project to analyze the house performance to this extent, although it does give an indication of what is required for future projects if the furnace performance is to be isolated.

For this study, degree days were calculated to a datum of 18 deg C. This method is consistant with Atmospheric Environment Services procedure. A measurement of actual degree days, based on the differential between outside temperature and actual interior temperature is essential to accurately calculate furnace efficiency. This could be achieved with the use of an instrument designed to record the temperature differential between outside and inside the house. We are presently researching and developing a simple electronic interface for the strip chart recorders used in this study, to simultaneously record a temperature differential and the rate of furnace cycling.

On the basis of the data produced in this study, it can be concluded that the number of uncontrolled variables restrict the analysis of the effects of furnace oversizing on seasonal efficiency.

In summary, this report has highlighted the importance of the various control systems associated with the furnace operation. It has shown that a large range of control configurations can be set up for any individual design of furnace, and that these configurations can have a considerable effect on the way in which the furnace operates. It appears that factory furnace settings may not always be suited to the needs of the house.

It would be advantageous to conduct basic studies on furnace control systems in a controlled house environment to determine the extent to which the adjustment of furnace controls affect energy consumption in oil and gas fired, forced-air, furnaces. A future study should address the synergistic factors which contribute to seasonal furnace efficiency by systematically adjusting furnace fan settings, thermostat setpoints, and thermostat anticipator settings during a period of instrumented monitoring.

To comprehensively address the question of seasonal efficiency in oil and gas fired furnaces, a three phase study is suggested. This study would consist of the following components:

1. A literature search to determine the best methods for measuring the seasonal efficiency of oil or gas fired, forced-air furnaces. This survey of the literature should also document the range of methods used to size furnaces for residential applications.

2. A two week field study of six reference test houses. These houses should be of equal design and located in close proximity, to provide similar conditions of climate and daily access to the houses by the researchers. During this test period, furnace control settings would be systematically varied to provide data for sensitivity analyses of control setpoints.

3. A field study of fourteen additional test houses to monitor the effects of adjustments to fan settings, thermostat settings, and anticipator settings. During this test period, the experience of the researchers would be applied to optimize and record the operation of the heating systems in the houses.

The final report of such a study should document a test and evaluation procedure which could be used to assess the performance of furnaces under normal operating conditions. As well, the results of the study could be summarized in a manual which could be used for optimizing the performance of existing heating systems.

8. BIBLIOGRAPHY

Title	Modal Procedure for the ECAP Home Energy Survey
Author(s)	Ron Argue, Millbank Associates, Ottawa, Ontario
Publisher/Date/Pages	Buildings and Urban Energy Division, Conservation and Renewable Energy Branch, Energy Mines and Resources, Canada/ November 1981/ 44 pages
Available from/Price	
Catalogue & Indexing Numbers	
Key Words	Energy conservation/ building systems/ performance evaluation/ home energy survey
Sector Applicability	Residential

A detailed procedure for measurement of space heating requirements and priorized retrofit options in houses. Although specifically designed for the Ottawa region, this procedure may be applicable to other parts of Canada. Certain critical assumptions, such as air exchange rates based on perceived moisture levels, would have to be adjusted for regional differences.

Title	Energy Conservation in New Small Residential Buildings
Author(s)	John C. Haysom, Scanada Consultants Limited, Ottawa
Publisher/Date/Pages	Canada Mortgage and Housing Corporation/ 1981/ 73 pages
Available from/Price	Technical Research Division, CMHC, National Office, Montreal Road, Ottawa, Ontario $1.50
Catalogue & Indexing Numbers	Cat. # NH 17-15/1981E ISBN 0-660-10925-2
Key Words	thermal resistance/ insulation/ air leakage/ building technology
Sector Applicability	Residential

A particularly good summary document describing energy conserving features which should be an integral part of new house construction. Some examples of retrofit options can be inferred.

Title	Heat Balance and Efficiency Measurements of Central Forced Air Residential Gas Furnaces
Author(s)	Eugene C. Hise, Allen S. Holman
Publisher/Date/Pages	Oakridge National Laboratory, Oakridge Tennessee/ 1977/ 18 pages
Available from/Price	Engineering Technology Division, Oakridge National Laboratory
Catalogue & Indexing Numbers	Paper prepared for presentation at ASHRAE Symposium, February 1977, Chicago, Illinois
Key Words	furnace/ gas/ efficiency/ controls
Sector Applicability	Residential

This study illustrates the effects of fan control setpoints and intermittent versus continuous fan operation on seasonal furnace efficiencies. The description of the testing procedure however, is inadequate.

Title	Estimating Energy Savings from Reinsulating Houses
Author(s)	R.L. Quirouette and E.C. Scheuneman
Publisher/Date/Pages	National Research Council/ May 1981
Available from/Price	Division of Building Research, NRC
Catalogue & Indexing Numbers	Report Number ISSN 0701-5216
Key Words	fuel bill/ savings/ Actual degree days/ air change rate/ retrofitting/ seasonal efficiency
Sector Applicability	Residential

A detailed study which examines methodologies for predicting the effects of energy conserving measures. Although well based on theory, the findings require field validation and sensetivity analysis.

Title	Thermal Efficiency in Existing Houses and the Potential for Conservation-Background Papers
Author(s)	Scanada Consultants Limited, Ottawa, Ontario
Publisher/Date/Pages	Central Mortgage and Housing Corporation/ 1976
Available from/Price	Policy Development Division, CMHC
Catalogue & Indexing Numbers	
Key Words	Energy conservation/ housing stock/ fuel costs/ thermal upgrade
Sector Applicability	Residential

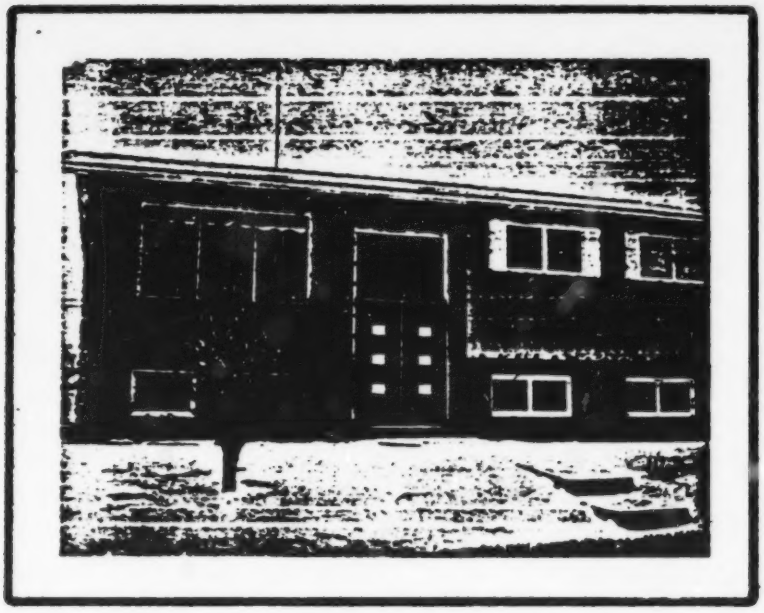
An early study which addresses many of the concerns regarding energy conservation options in residential buildings. This study provides the basis for more definitive research.

Title	A Time Constant Test for House Thermal Performance Evaluation
Author(s)	Jim H. White
Publisher/Date/Pages	Canada Mortgage and Housing Corporation/ December 1981/ 11 pages
Available from/Price	Draft Issue
Catalogue & Indexing Numbers	
Key Words	interior temperature/ exterior temperature/ envelope loss/ heat input/ thermal time constant
Sector Applicability	Residential

A definitive study which describes a potentially valuable methodology for measuring thermal performance of houses. In particular, the methodologies could be easily implemented in the field with a minimum of instrumentation.

APPENDIX A

Study House Data



LIVINGSTONE RESIDENCE

U of C KANANASKIS CENTRE

BUILDING ENERGY DESIGN ANALYSIS

A program to calculate theoretical heat loss of low energy buildings,
modified from NRC DBR-R. Dumont(1981) by U of C KANANASKIS-M. Youso

********** DESIGN INPUT DATA **********

SRC FURNACE PERFORMANCE EVALUATION
Livingstone Residence; 1968 bi-level; 1 ac/hr; 100F design temp diff

DESIGN TEMPERATURE: -33 DEGREES CELSIUS
MAIN FLOOR TEMP 22.5 BASEMENT TEMP 20 GROUND WATER TEMP 4
DESIGN TEMP DIFF (ABOVE GROUND) 55.5 (BELOW GROUND) 16 DEG C

****U of C KANANASKIS CENTRE*******BUILDING ENERGY DESIGN ANALYSIS****

ELEMENT	AREA M2	RSI VALUE M2-DEGC/W	HT LOSS W/DEG C	SEASONAL % HT LOSS
CEILING	90.60	10.21	8.87	2.39
WALLS	139.10	1.20	115.92	31.27
WINDOWS,S	1.39	0.36	3.86	1.04
WINDOWS,NON-S	16.20	0.36	45.00	12.14
DOORS	6.85	0.50	13.70	3.70
BSMENT,AB.GD.	0.00	0.00	0.00	0.00
BSMENT,BL.GD.	47.60	2.10	15.97	3.45
FLOOR	90.60	0.36	42.74	9.22
AIR CHANGE	----	----	136.34	36.78

BUILDING VOLUME(M3)= 442 AIR CHANGE/HR: HEATED= 1.00 TOTAL= 1.00

HT LOSS ALL WINDOWS	(W/DEG C)	48.86
HT LOSS ABV GND,EXCL ALL WINDW	(W/DEG C)	274.83
HT LOSS BELOW GRADE WALLS	(W/DEG C)	15.97
HT LOSS BELOW GRADE FLOOR	(W/DEG C)	42.74
TOTAL HT LOSS: EFFECTIVE UA	(W/DEG C)	370.66
AVG HT TRANSMITTANCE ABV GND	(W/M2-DEG C)	1.27

TOTAL HEAT LOSS 18904(WATTS) 64520(BTU/HR) AT DESIGN TEMP: -33 DEG C

VOLUME FOR THE BUILDING (CUBIC METRES)	M3= CU. FT./35.31
AREA FOR ELEMENT OF THE BUILDING (SQ. METRES)	M2= SQ. FT./10.76
HEAT RESISTANCE OF ELEMENT (M2-C/W)	RSI= R/5.678
HEAT LOSS OF ELEMENT (WATTS)	WATTS * 3.413 = BTU/HR

HOUSE DATA

CASE:..... Livingstone Residence

CONSTRUCTION TYPE:..... wood frame

FORM:..... bi-level bungalow

HEATED FLOOR AREA (M2):..... 181

YEAR BUILT:..... 1969

OCCUPANCY:..... family of four

STOVES:..... electric

ELECTRIC HEATING DEVICES:.... 'electric fire' not in use

FLUES:..... furnace & DHW

FIREPLACES/ DAMPERS:..... none - dryer vented to outside

APPARENT MOISTURE SOURCES:... steam bath (1 kW electric) used 1-2 times weekly

ANOMALIES & IDIOSYNCRASIES:
- six out of nine main floor heating distribution ducts normally closed
- attached garage maintained at 40 deg F
- sheer curtains or drapes on all windows
- furnace filter cleaned twice/ month - furnace room exceptionally clean
- In the context of this study, occupants represent a 'typical' family

FURNACE DATA

MAKE/ MODEL; YEAR INSTALLED: Chrysler Airtemp 4212-10H; 1969
Rated output BTU/H : 86400

AIR HANDLING SYSTEM

TEMPERATURES (deg C): SUPPLY DUCT (BONNET): 86 ; RETURN AIR: 26

AIRFLOW (M/s, CFM): SUPPLY DUCT (BONNET): 2.4, 1143 ; RETURN AIR: 0.8, 406

BLOWER MOTOR SIZE: 1/4 hp. RATED CFM: not available

FAN CONTROL (deg F): ON: 90 OFF: 80 LIMIT: 110 fan switch on

RESET: 29 March 1982 ON: -- OFF: -- LIMIT: 200

STEADY STATE COMBUSTION EFFICIENCY

PERCENTAGE EFFICIENCY: 78 BACKDRAFTING (Y/N): N

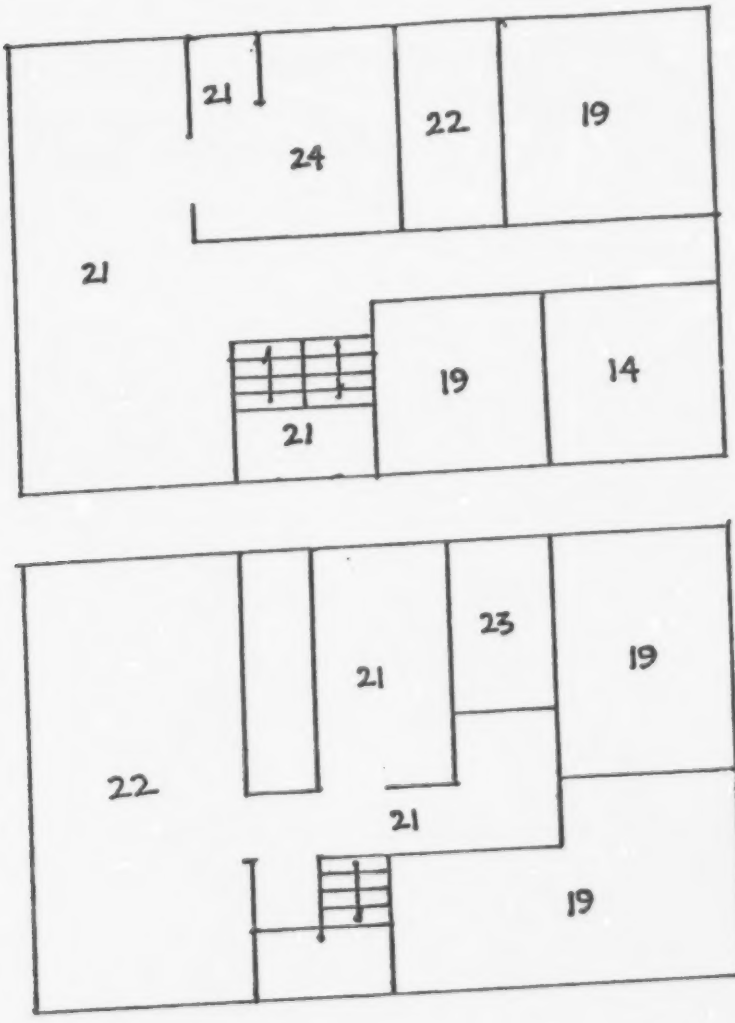
PERCENT OXYGEN: 7 STACK TEMPERATURE (deg C): 265

THERMOSTAT

TEMPERATURE SCHEDULE: 0500 -22.5/ 2330 - 15.0

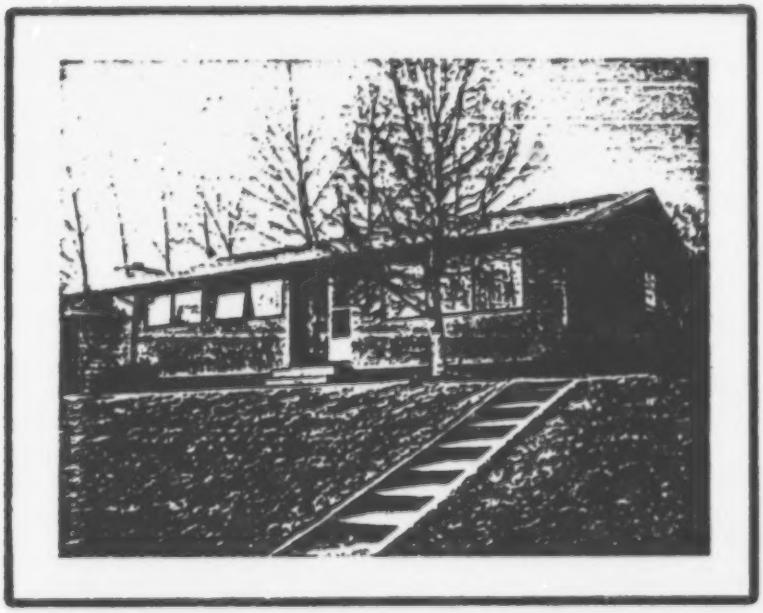
INITIAL ANTICIPATOR SETTING: .35 RESET: 1.0 DATE: 29 March 1982

FLOOR PLAN SCHEMATIC
(1" = 10')



MEAN RADIANT SURFACE TEMPERATURES (deg C)
AS MEASURED IN ALL ZONES OF LIVING AREA

OWNER/ BUILDER:	Livinstone Residence
DATE/ TIME:	31 March 1982
BASEMENT TEMP:	as Illustrated
OUTSIDE TEMP (deg C):	00
SKY CONDITIONS:	broken overcast



HALL RESIDENCE

U of C KANANASKIS CENTRE

BUILDING ENERGY DESIGN ANALYSIS

A program to calculate theoretical heat loss of low energy buildings,
modified from NRC DBR-R. Dumont(1981) by U of C KANANASKIS-M. Youso

********** DESIGN INPUT DATA **********

SRC FURNACE PERFORMANCE EVALUATION
Hall Residence: 1959 bungalow; 1 ac/hr; 100F design temp diff

DESIGN TEMPERATURE: -33 DEGREES CELSIUS
MAIN FLOOR TEMP 22.5 BASEMENT TEMP 20 GROUND WATER TEMP 4
DESIGN TEMP DIFF (ABOVE GROUND) 55.5 (BELOW GROUND) 16 DEG C

****U of C KANANASKIS CENTRE*******BUILDING ENERGY DESIGN ANALYSIS****

ELEMENT	AREA M2	RSI VALUE M2-DEGC/W	HT LOSS W/DEG C	SEASONAL % HT LOSS
CEILING	103.00	5.70	18.07	4.61
WALLS	89.00	1.20	74.17	18.91
WINDOWS,S	8.25	0.36	22.92	5.84
WINDOWS,NON-S	6.13	0.36	17.03	4.34
DOORS	1.73	0.36	4.81	1.23
BSMENT,AB.GD.	36.90	1.07	34.49	8.79
BSMENT,BL.GD.	63.50	1.07	32.56	6.64
FLOOR	103.00	0.28	50.49	10.30
AIR CHANGE	----	----	154.23	39.33

BUILDING VOLUME(M3)= 500 AIR CHANGE/HR: HEATED= 1.00 TOTAL= 1.00

HT LOSS ALL WINDOWS	(W/DEG C)	39.94
HT LOSS ABV GND,EXCL ALL WINDW	(W/DEG C)	285.76
HT LOSS BELOW GRADE WALLS	(W/DEG C)	32.56
HT LOSS BELOW GRADE FLOOR	(W/DEG C)	50.49
TOTAL HT LOSS: EFFECTIVE UA	(W/DEG C)	392.15
AVG HT TRANSMITTANCE ABV GND	(W/M2-DEG C)	1.33

TOTAL HEAT LOSS 19405(WATTS) 66230(BTU/HR) AT DESIGN TEMP: -33 DEG C

VOLUME FOR THE BUILDING (CUBIC METRES) M3= CU. FT./35.31
AREA FOR ELEMENT OF THE BUILDING (SQ. METRES) M2= SQ. FT./10.76
HEAT RESISTANCE OF ELEMENT (M2-C/W) RSI= R/5.678
HEAT LOSS OF ELEMENT (WATTS) WATTS * 3.413 = BTU/HR

HOUSE DATA

CASE:..... Hall Residence

CONSTRUCTION TYPE:..... wood frame

FORM:..... 1 story bungalow

HEATED FLOOR AREA (M2):..... 206 (includes basement)

YEAR BUILT:..... 1959

OCCUPANCY:..... four: two on main floor/ two in basement

STOVES:..... electric

ELECTRIC HEATING DEVICES:.... 1 kW heater in basement

FLUES:..... furnace & DHW

FIREPLACES/ DAMPERS:..... none - dryer vented to outside

APPARENT MOISTURE SOURCES:... none

ANOMALIES & IDIOSYNCRASIES:
- basement actively used as office space during day
- one south main floor window open continuously; door often open on sunny days
- setback thermostat installed 08 March did not function properly
- replaced with original thermostat 14 March, new setback unit 22 March
- six inch diameter humidifier bypass duct between supply and return
- humidifier inoperative
- no combustion air duct

FURNACE DATA

MAKE/ MODEL; YEAR INSTALLED: Furnace Aire 125 FLBK ; 1959
Rated output BTU/H: 100,000

AIR HANDLING SYSTEM

TEMPERATURES (deg C): SUPPLY DUCT (BONNET): 75 ; RETURN AIR: 25

AIRFLOW (M/s, CFM): SUPPLY DUCT (BONNET): .7, 296 ; RETURN AIR: .5, 212

BLOWER MOTOR SIZE: 1/4 hp RATED CFM: not available

FAN CONTROL (deg F): ON: 150 OFF: 100 LIMIT: 200 fan switch on

RESET: 10 March 1982 ON: 100 OFF: 75 LIMIT: --

STEADY STATE COMBUSTION EFFICIENCY

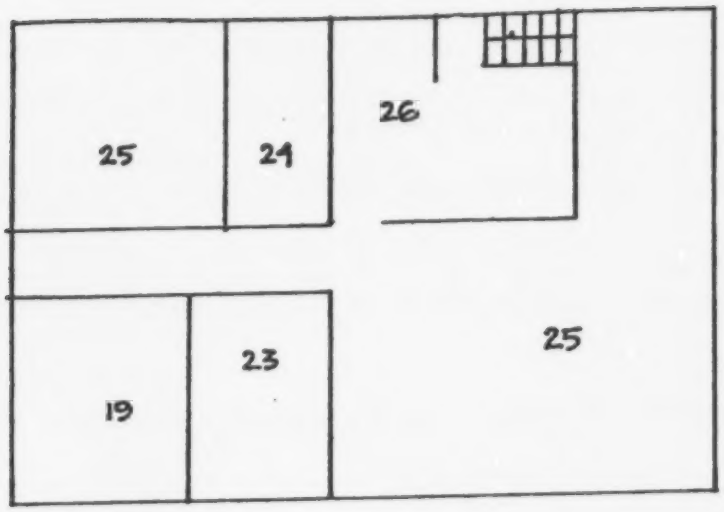
PERCENTAGE EFFICIENCY: 75 BACKDRAFTING (Y/N): N

PERCENT OXYGEN: 10.5 STACK TEMPERATURE (deg C): 246

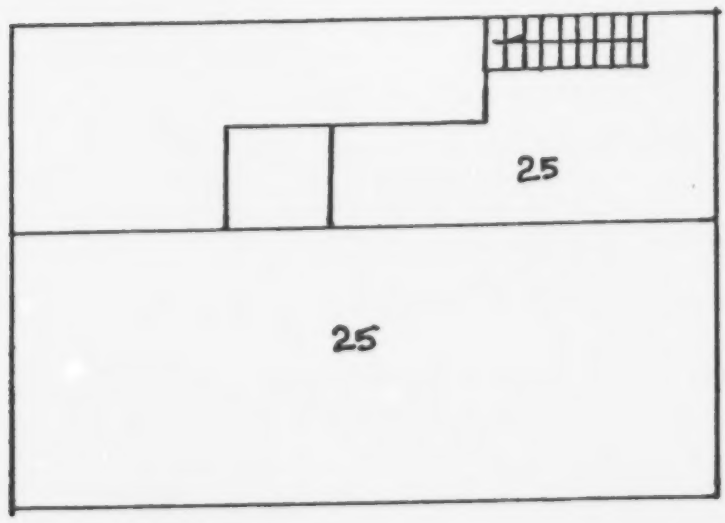
THERMOSTAT

TEMPERATURE SCHEDULE: 0600 - 22.5 / 2400 - 15.0
INITIAL ANTICIPATOR SETTING: .35 RESET: 1.0 DATE: 29 March 1982

FLOOR PLAN SCHEMATIC
(1" = 10')



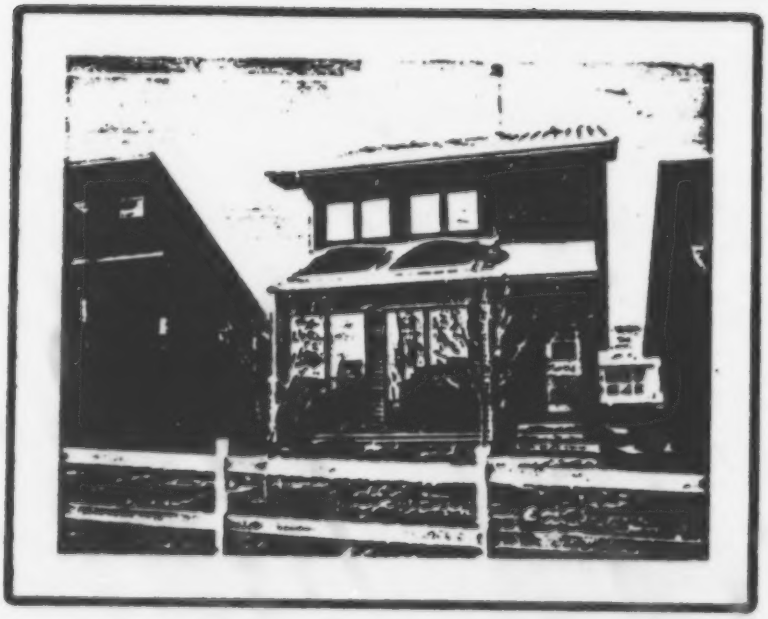
MAIN FLOOR



BASEMENT

MEAN RADIANT SURFACE TEMPERATURES (deg C)
AS MEASURED IN ALL ZONES OF LIVING AREA

OWNER/ BUILDER:	Hall Residence
DATE/ TIME:	31 March 1982/ 1300
BASEMENT TEMP:	as illustrated
OUTSIDE TEMP (deg C):	02
SKY CONDITIONS:	broken overcast



CAIRNS HOME

U of C KANANASKIS CENTRE

BUILDING ENERGY DESIGN ANALYSIS

A program to calculate theoretical heat loss of low energy buildings, modified from NRC DBR-R. Dumont(1981) by U of C KANANASKIS-M. Youso

********** DESIGN INPUT DATA **********

SRC FURNACE PERFORMANCE EVALUATION
Cairns Home; 1981 two story; air/air heat exch.; tight v.b.;
100F design temp diff

DESIGN TEMPERATURE: -33 DEGREES CELSIUS
MAIN FLOOR TEMP 22.5 BASEMENT TEMP 20 GROUND WATER TEMP 4
DESIGN TEMP DIFF (ABOVE GROUND) 55.5 (BELOW GROUND) 16 DEG C

****U of C KANANASKIS CENTRE********BUILDING ENERGY DESIGN ANALYSIS****

ELEMENT	AREA M2	RSI VALUE M2-DEGC/W	HT LOSS W/DEG C	SEASONAL % HT LOSS
CEILING	165.60	8.10	20.44	8.08
WALLS	215.50	4.10	52.56	20.78
WINDOWS,S	15.60	0.49	31.84	12.59
WINDOWS,NON-S	14.30	0.49	29.18	11.54
DOORS	3.60	1.00	3.60	1.42
BSMENT,AB.GD.	9.10	0.56	16.25	6.43
BSMENT,BL.GD.	84.10	2.90	22.25	7.04
FLOOR	71.70	2.00	19.07	6.03
AIR CHANGE	----	----	65.98	26.09

BUILDING VOLUME(M3)= 618 AIR CHANGE/HR: HEATED= 0.35 TOTAL= 0.45

HT LOSS ALL WINDOWS	(W/DEG C)	61.02
HT LOSS ABV GND,EXCL ALL WINDW	(W/DEG C)	158.84
HT LOSS BELOW GRADE WALLS	(W/DEG C)	22.25
HT LOSS BELOW GRADE FLOOR	(W/DEG C)	19.07
TOTAL HT LOSS: EFFECTIVE UA	(W/DEG C)	252.91
AVG HT TRANSMITTANCE ABV GND	(W/M2-DEG C)	0.52

TOTAL HEAT LOSS 12863(WATTS) 43901(BTU/HR) AT DESIGN TEMP: -33 DEG C

VOLUME FOR THE BUILDING (CUBIC METRES) M3= CU. FT./35.31
AREA FOR ELEMENT OF THE BUILDING (SQ. METRES) M2= SQ. FT./10.76
HEAT RESISTANCE OF ELEMENT (M2-C/W) RSI= R/5.678
HEAT LOSS OF ELEMENT (WATTS) WATTS * 3.413 = BTU/HR

HOUSE DATA

CASE:..... Cairns Home

CONSTRUCTION TYPE:..... wood frame, 2x6 stud wall, "superinsulated"

FORM:..... 2 story

HEATED FLOOR AREA (M2):..... 214

YEAR BUILT:..... 1981

OCCUPANCY:..... unoccupied

STOVES:..... electric

ELECTRIC HEATING DEVICES:.... none;dryer vents to A/A heat exchanger, not used

FLUES:..... none; electric DHW heater, flueless furnace

FIREPLACES/ DAMPERS:..... fireplace(not used) w/ glass doors, damper closed

APPARENT MOISTURE SOURCES:... none

ANOMALIES & IDIOSYNCRASIES:
- A/A heat exchanger operating at low fan speed during test period
- intermittent daytime occupancy by realtors
- curtains closed on most non-south windows
- attached sunspace provides solar gain preheat to basement
- furnace room isolated; sealed @ bottom & sides

FURNACE DATA

MAKE/ MODEL; YEAR INSTALLED: Clare H.E.G. 80 gas condensing; 1981
Rated output BTU/H : 67000

AIR HANDLING SYSTEM

TEMPERATURES (deg C): SUPPLY DUCT (BONNET): 126 ; RETURN AIR: 26

AIRFLOW (M/s, CFM): SUPPLY DUCT (BONNET): 2.2, 652 ; RETURN AIR: 0.8, 425

BLOWER MOTOR SIZE: 1/3 hp RATED CFM: 800 @ .3" W.C.

FAN CONTROL (deg F): ON: 100 OFF: 75 LIMIT: 175 fan switch on

STEADY STATE COMBUSTION EFFICIENCY

PERCENTAGE EFFICIENCY: 87 BACKDRAFTING (Y/N): N

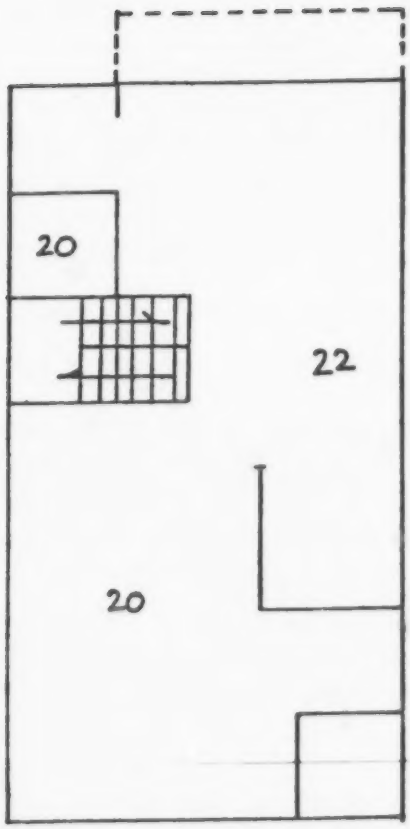
PERCENT OXYGEN: 11 STACK TEMPERATURE (deg C): 53

THERMOSTAT

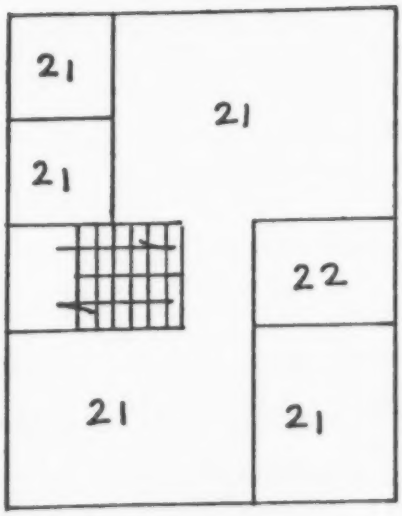
TEMPERATURE SCHEDULE: 0600-22.5/1000-15.0/1630-22.5/2400-15.0

INITIAL ANTICIPATOR SETTING: .7 RESET: 1.0 DATE: 29 March 1982

FLOOR PLAN SCHEMATIC
(1" = 10')



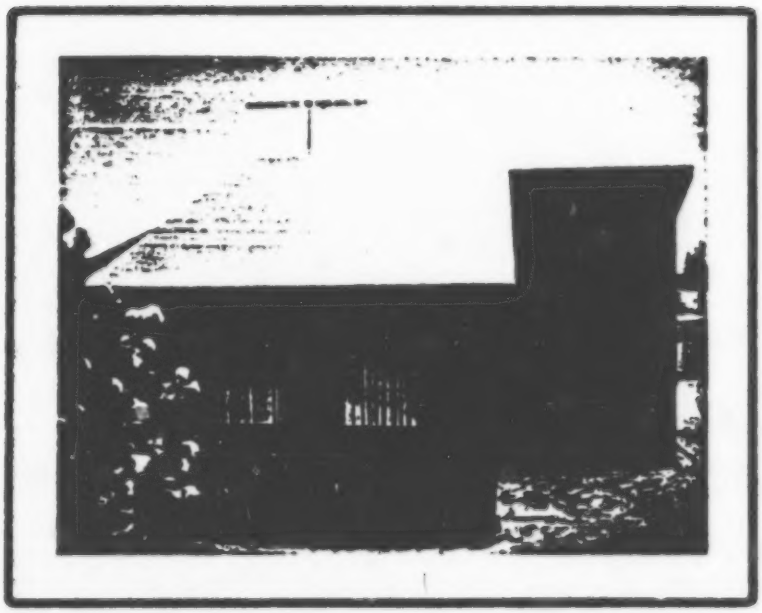
MAIN LIVING AREA



UPPER FLOOR AREA

MEAN RADIANT SURFACE TEMPERATURES (deg C)
AS MEASURED IN ALL ZONES OF LIVING AREA

OWNER/ BUILDER:	Cairns Home
DATE/ TIME:	31 March 1982/ 1700
BASEMENT TEMP:	20
OUTSIDE TEMP (deg C):	01
SKY CONDITIONS:	broken overcast



KANANASKIS 5A

U of C KANANASKIS CENTRE

BUILDING ENERGY DESIGN ANALYSIS

A program to calculate theoretical heat loss of low energy buildings,
modified from NRC DBR-R. Dumont(1981) by U of C KANANASKIS-M. Youso

********** DESIGN INPUT DATA **********

SRC FURNACE PERFORMANCE EVALUATION
Kana 5A; 1968 open beam w/ loft; 1 ac/hr; 100F design temp diff

DESIGN TEMPERATURE: -33 DEGREES CELSIUS
MAIN FLOOR TEMP 22.5 BASEMENT TEMP 18 GROUND WATER TEMP 4
DESIGN TEMP DIFF (ABOVE GROUND) 55.5 (BELOW GROUND) 14 DEG C

****U of C KANANASKIS CENTRE*******BUILDING ENERGY DESIGN ANALYSIS****

ELEMENT	AREA M2	RSI VALUE M2-DEGC/W	HT LOSS W/DEG C	SEASONAL % HT LOSS
CEILING	66.40	5.20	12.77	5.52
WALLS	98.80	2.70	36.59	15.82
WINDOWS,S	1.80	0.50	3.60	1.56
WINDOWS,NON-S	7.30	0.50	14.60	6.31
DOORS	1.81	0.50	3.62	1.57
BSMENT,AB.GD.	35.50	1.10	32.27	13.95
BSMENT,BL.GD.	21.30	0.31	17.90	6.19
FLOOR	54.70	0.00	31.06	10.74
AIR CHANGE	----	----	88.68	38.34

BUILDING VOLUME(M3)= 288 AIR CHANGE/HR: HEATED= 1.00 TOTAL= 1.00

HT LOSS ALL WINDOWS	(W/DEG C)	18.20
HT LOSS ABV GND,EXCL ALL WINDW	(W/DEG C)	173.94
HT LOSS BELOW GRADE WALLS	(W/DEG C)	17.90
HT LOSS BELOW GRADE FLOOR	(W/DEG C)	31.06
TOTAL HT LOSS: EFFECTIVE UA	(W/DEG C)	231.31
AVG HT TRANSMITTANCE ABV GND	(W/M2-DEG C)	0.91

TOTAL HEAT LOSS 11349(WATTS) 38734(BTU/HR) AT DESIGN TEMP: -33 DEG C

VOLUME FOR THE BUILDING (CUBIC METRES) M3= CU. FT./35.31
AREA FOR ELEMENT OF THE BUILDING (SQ. METRES) M2= SQ. FT./10.76
HEAT RESISTANCE OF ELEMENT (M2-C/W) RSI= R/5.678
HEAT LOSS OF ELEMENT (WATTS) WATTS * 3.413 = BTU/HR

HOUSE DATA

CASE:..... Kananaskis 5A

CONSTRUCTION TYPE:..... wood frame

FORM:..... 1 story L-form, open beam and deck ceiling

HEATED FLOOR AREA (M2):..... 55 (excluding heated crawlspace)

YEAR BUILT:..... 1968

OCCUPANCY:..... one: single professional

STOVES:..... electric

ELECTRIC HEATING DEVICES:.... none

FLUES:..... furnace

FIREPLACES/ DAMPERS:..... none

APPARENT MOISTURE SOURCES:... none

ANOMALIES & IDIOSYNCRASIES:
- house unoccupied during day
- thermostat setback to 64 during extended periods of absence

FURNACE DATA

MAKE/ MODEL; YEAR INSTALLED: Lennox G8R 82T downdraft propane; 1968
Rated output BTU/H : 65600

AIR HANDLING SYSTEM

TEMPERATURES (deg C): SUPPLY DUCT (BONNET): 90 ; RETURN AIR: 22

AIRFLOW (M/s, CFM): SUPPLY DUCT (BONNET): 1.2, 267 ; RETURN AIR: 0.4, 137

BLOWER MOTOR SIZE: 1/4 hp RATED CFM: 700 @ .5" W.C.

FAN CONTROL (deg F): ON: 125 OFF: 90 LIMIT: 200 fan switch on

STEADY STATE COMBUSTION EFFICIENCY

PERCENTAGE EFFICIENCY: 74 BACKDRAFTING (Y/N): N

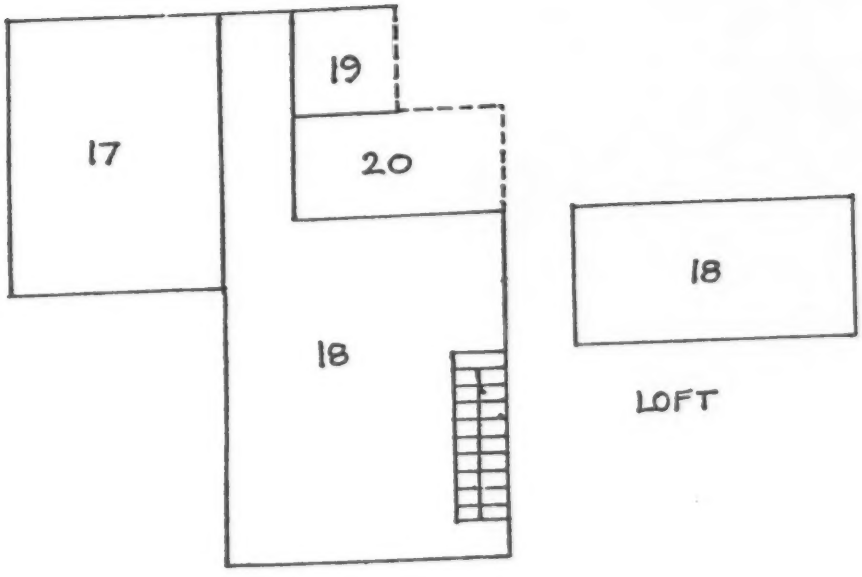
PERCENT OXYGEN: 9 STACK TEMPERATURE (deg C): 285

THERMOSTAT

TEMPERATURE SCHEDULE: 0500 - 20.0 / 2300 - 15.0

INITIAL ANTICIPATOR SETTING: 1.0 RESET: -- DATE: --

FLOOR PLAN SCHEMATIC
(1" = 10')



MEAN RADIANT SURFACE TEMPERATURES (deg C)
AS MEASURED IN ALL ZONES OF LIVING AREA

OWNER/ BUILDER:	Kananaskis 5A
DATE/ TIME:	30 March 1982/ 2100
BASEMENT TEMP:	13 (crawlspace)
OUTSIDE TEMP (deg C):	-05
SKY CONDITIONS:	overcast

EDGEMONT HOME

U of C KANANASKIS CENTRE

BUILDING ENERGY DESIGN ANALYSIS

A program to calculate theoretical heat loss of low energy buildings,
modified from NRC DBR-R. Dumont(1981) by U of C KANANASKIS-M. Youso

********** DESIGN INPUT DATA **********

SRC FURNACE PERFORMANCE EVALUATION
Edgemont Home; 1981 1.5 story;; air/air heat exch; tight v.b.;
100F design temp diff

DESIGN TEMPERATURE: -33 DEGREES CELSIUS
MAIN FLOOR TEMP 22.5 BASEMENT TEMP 18 GROUND WATER TEMP 4
DESIGN TEMP DIFF (ABOVE GROUND) 55.5 (BELOW GROUND) 14 DEG C

****U of C KANANASKIS CENTRE*******BUILDING ENERGY DESIGN ANALYSIS****

ELEMENT	AREA M2	RSI VALUE M2-DEGC/W	HT LOSS W/DEG C	SEASONAL % HT LOSS
CEILING	104.00	10.60	9.81	5.62
WALLS	200.50	9.90	20.25	11.59
WINDOWS,S	14.30	0.57	25.09	14.36
WINDOWS,NON-S	4.70	0.57	8.25	4.72
DOORS	4.70	2.40	1.96	1.12
BSMENT,AB.GD.	7.20	3.50	2.06	1.18
BSMENT,BL.GD.	81.50	3.50	18.61	8.52
FLOOR	91.00	2.00	24.20	11.08
AIR CHANGE	----	----	73.01	41.80

BUILDING VOLUME(M3)= 694 AIR CHANGE/HR: HEATED= 0.34 TOTAL= 0.44

HT LOSS ALL WINDOWS	(W/DEG C)	33.33
HT LOSS ABV GND,EXCL ALL WINDW	(W/DEG C)	107.09
HT LOSS BELOW GRADE WALLS	(W/DEG C)	18.61
HT LOSS BELOW GRADE FLOOR	(W/DEG C)	24.20
TOTAL HT LOSS: EFFECTIVE UA	(W/DEG C)	174.67
AVG HT TRANSMITTANCE ABV GND	(W/M2-DEG C)	0.42

TOTAL HEAT LOSS 8392(WATTS) 28645(BTU/HR) AT DESIGN TEMP: -33 DEG C

VOLUME FOR THE BUILDING (CUBIC METRES) M3= CU. FT./35.31
AREA FOR ELEMENT OF THE BUILDING (SQ. METRES) M2= SQ. FT./10.76
HEAT RESISTANCE OF ELEMENT (M2-C/W) RSI= R/5.678
HEAT LOSS OF ELEMENT (WATTS) WATTS * 3.413 = BTU/HR

HOUSE DATA

CASE:..... Edgemont Home

CONSTRUCTION TYPE:..... wood frame, double stud wall, "superinsulated"

FORM:..... one and a half story

HEATED FLOOR AREA (M2):..... 154 (excludes basement)

YEAR BUILT:..... 1981

OCCUPANCY:..... unoccupied

STOVES:..... electric

ELECTRIC HEATING DEVICES:.... none

FLUES:..... DHW only - flueless furnace

FIREPLACES/ DAMPERS:..... fireplace(not used) w/ glass doors, damper closed

APPARENT MOISTURE SOURCES:... none

ANOMALIES & IDIOSYNCRASIES:
- A/A heat exchanger operating at low fan speed during test period
- Intermittent daytime occupancy by workmen and realtors
- furnace room isolated, not sealed

FURNACE DATA

MAKE/ MODEL; YEAR INSTALLED: Clare H.E.G. 80 gas condensing ; 1981
Rated output BTU/H : 67000

AIR HANDLING SYSTEM

TEMPERATURES (deg C): SUPPLY DUCT (BONNET): 92 ; RETURN AIR: 24

AIRFLOW (M/s, CFM): SUPPLY DUCT (BONNET): 2.2, 652 ; RETURN AIR: 0.8, 425

BLOWER MOTOR SIZE: 1/3 hp RATED CFM: 800 @ 0.3" W.C.

FAN CONTROL (deg F): ON: 100 OFF: 75 LIMIT: 175 fan switch on

STEADY STATE COMBUSTION EFFICIENCY

PERCENTAGE EFFICIENCY: 88 BACKDRAFTING (Y/N): N

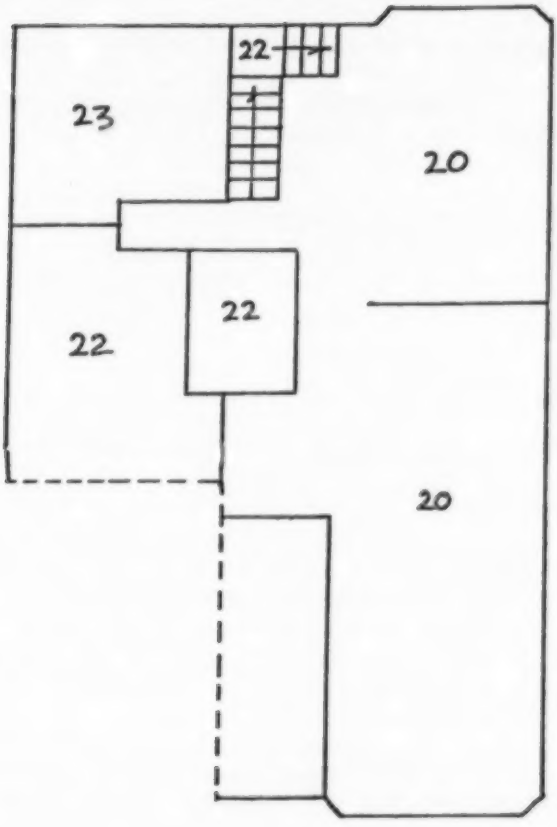
PERCENT OXYGEN: 9 STACK TEMPERATURE (deg C): 52

THERMOSTAT

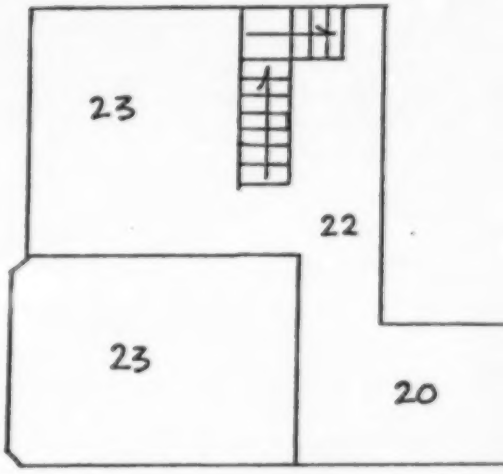
TEMPERATURE SCHEDULE: 0600-22.5/1000-15.0/1630-22.5/2400-15.0

INITIAL ANTICIPATOR SETTING: .35 RESET: 1.0 DATE: 29 March 1982

FLOOR PLAN SCHEMATIC
(1" = 10')



MAIN LIVING AREA



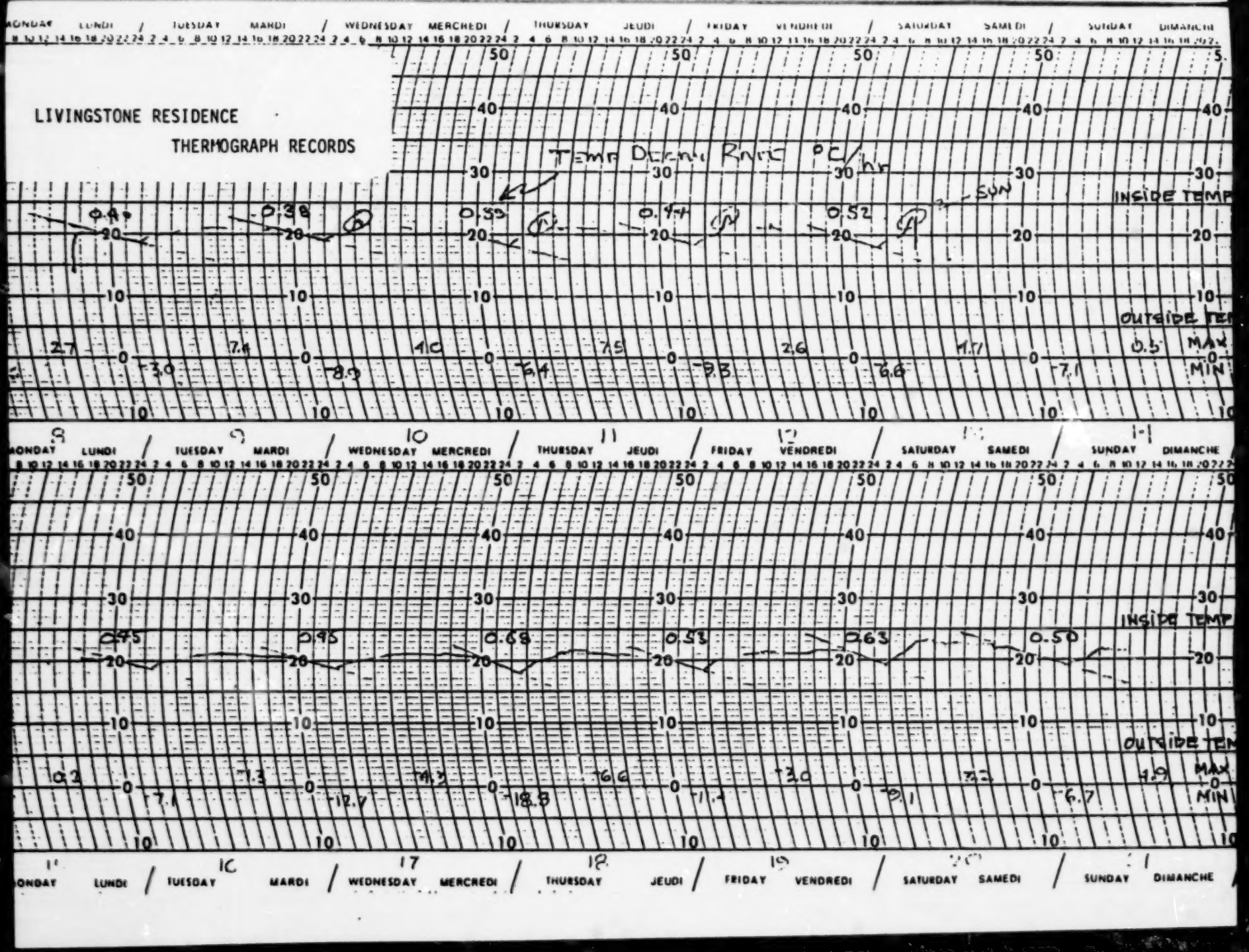
UPPER FLOOR AREA

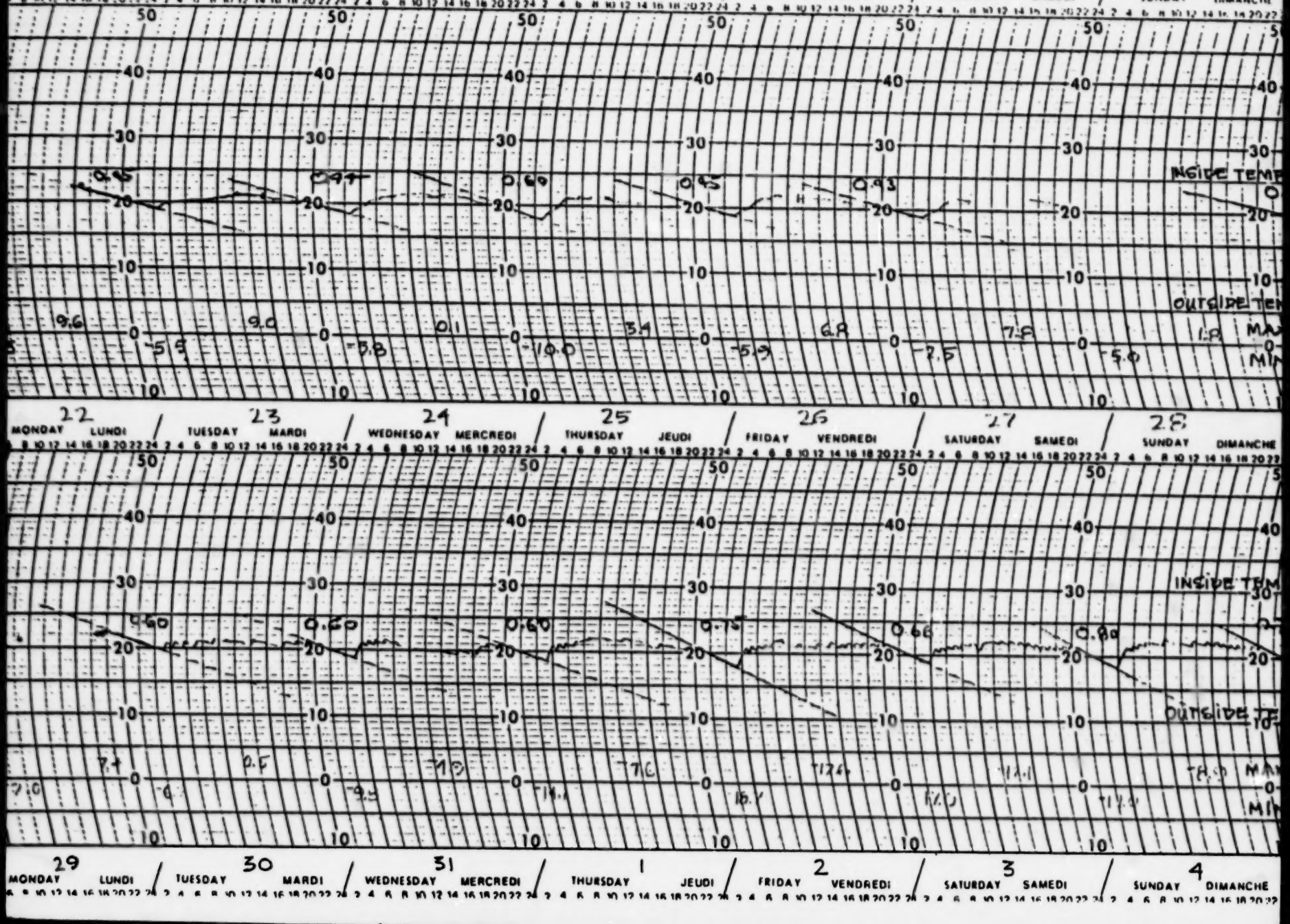
MEAN RADIANT SURFACE TEMPERATURES (deg C)
AS MEASURED IN ALL ZONES OF LIVING AREA

OWNER/ BUILDER:	Edgemont Home
DATE/ TIME:	31 March 1982/ 1900
BASEMENT TEMP:	17
OUTSIDE TEMP (deg C):	01
SKY CONDITIONS:	broken overcast

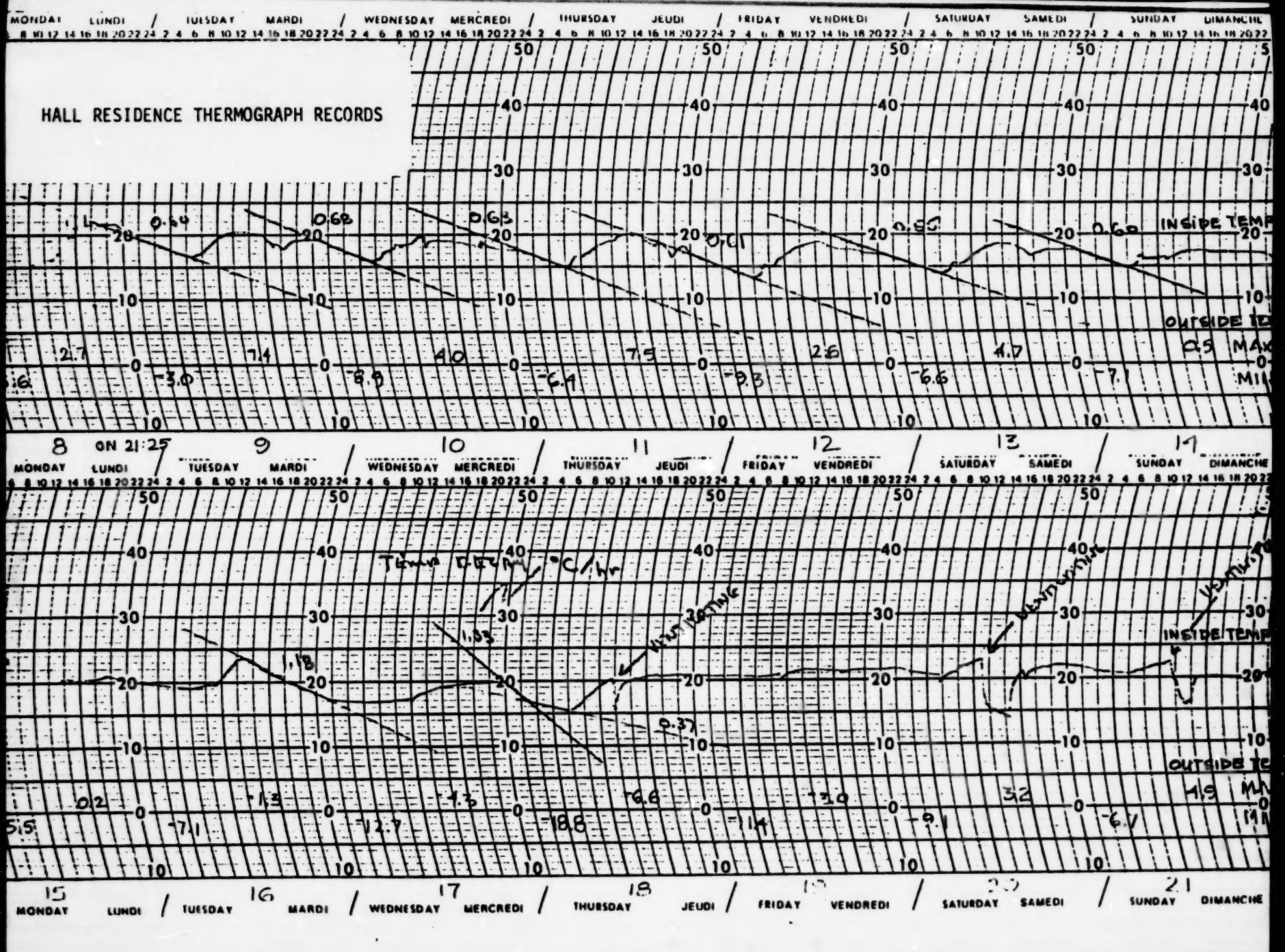
APPENDIX B

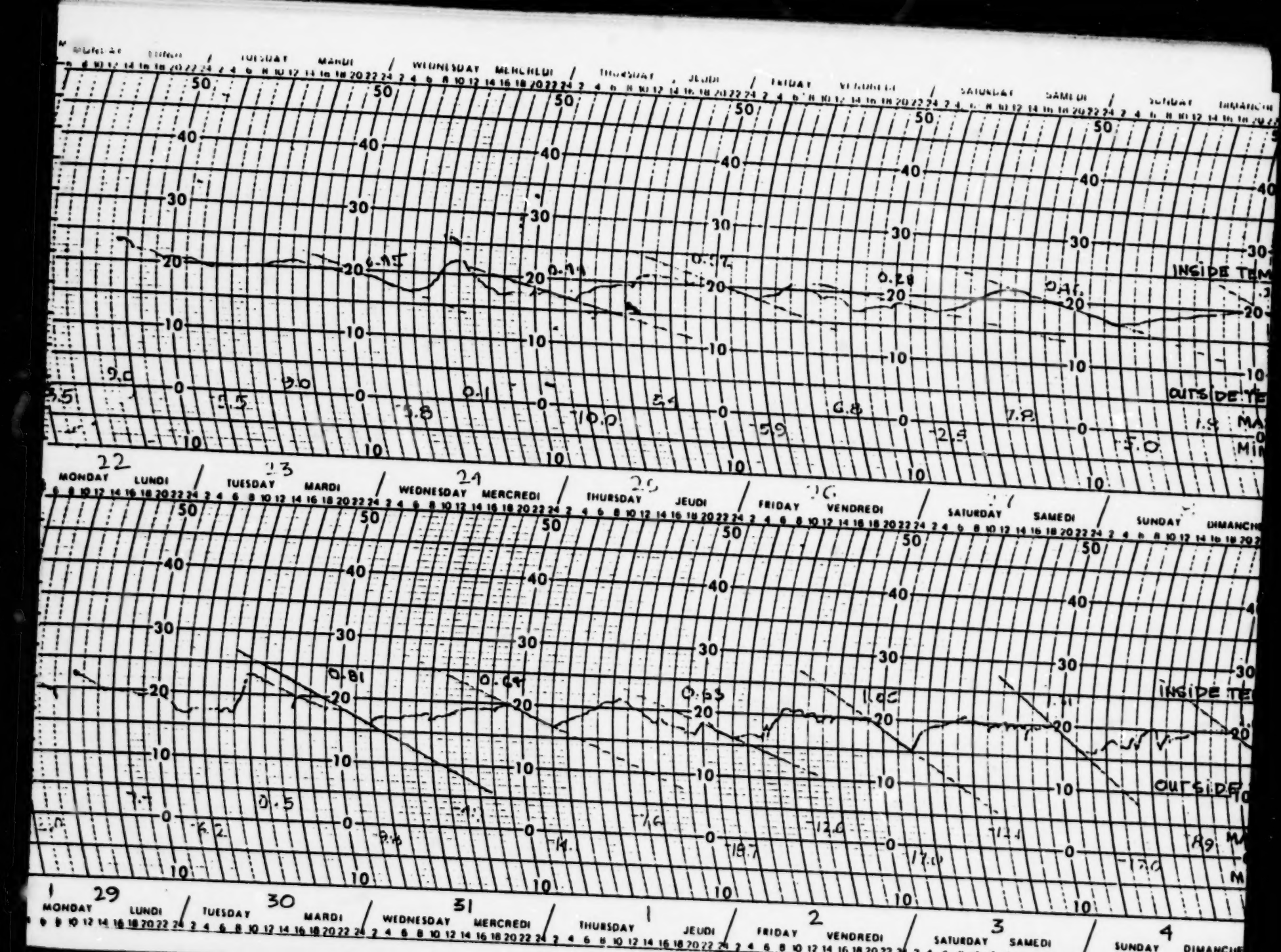
Thermograph Records for Study Houses

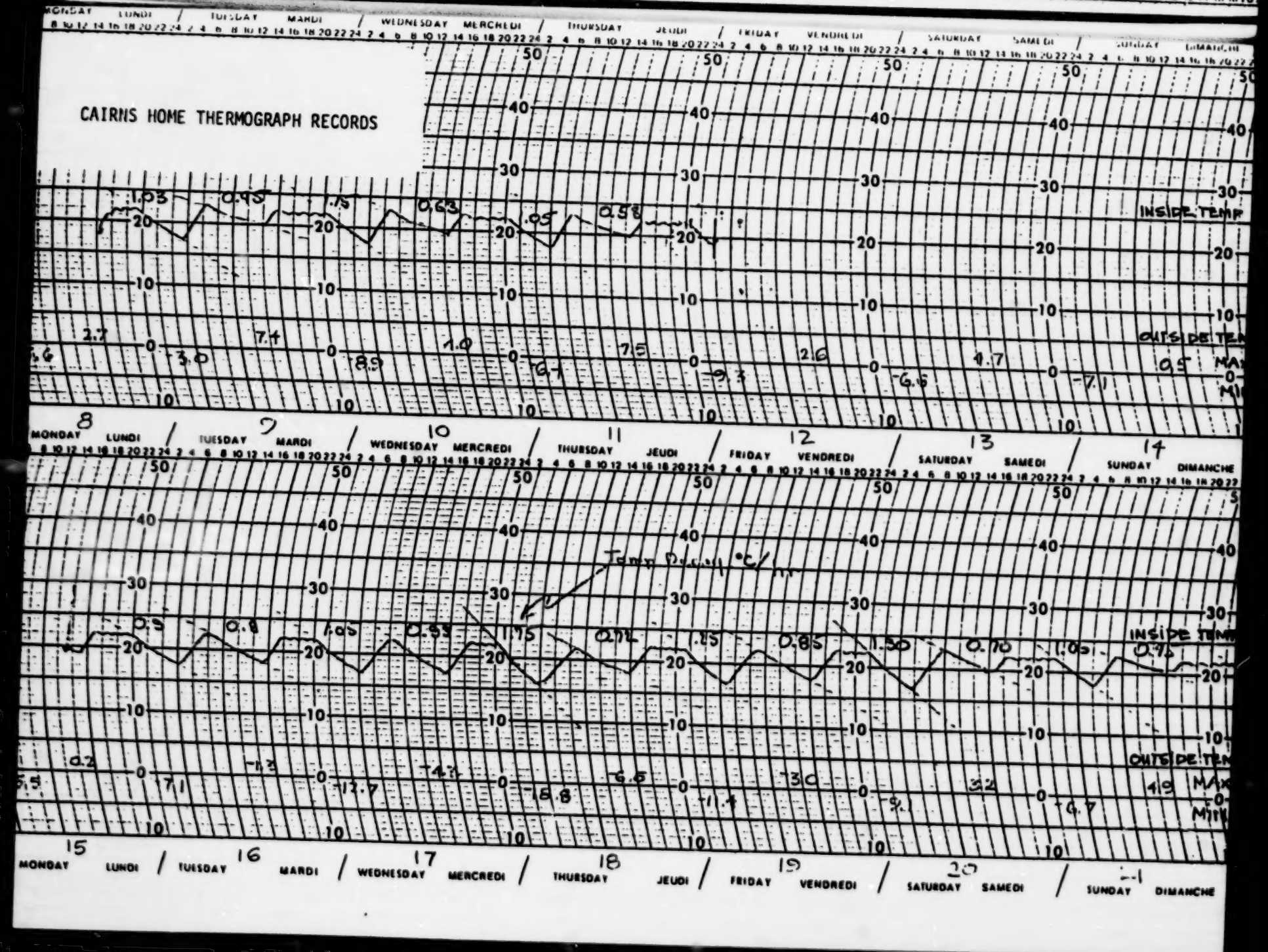

LIVINGSTONE RESIDENCE
THERMOGRAPH RECORDS
Temp Difference Rate °C/hr
INSIDE TEMP
OUTSIDE TEMP
MAX
MIN
MONDAY LUNDI / TUESDAY MARDI / WEDNESDAY MERCREDI / THURSDAY JEUDI / FRIDAY VENDREDI / SATURDAY SAMEDI / SUNDAY DIMANCHE
8 9 10 11 12 13 14
15 16 17 18 19 20 21

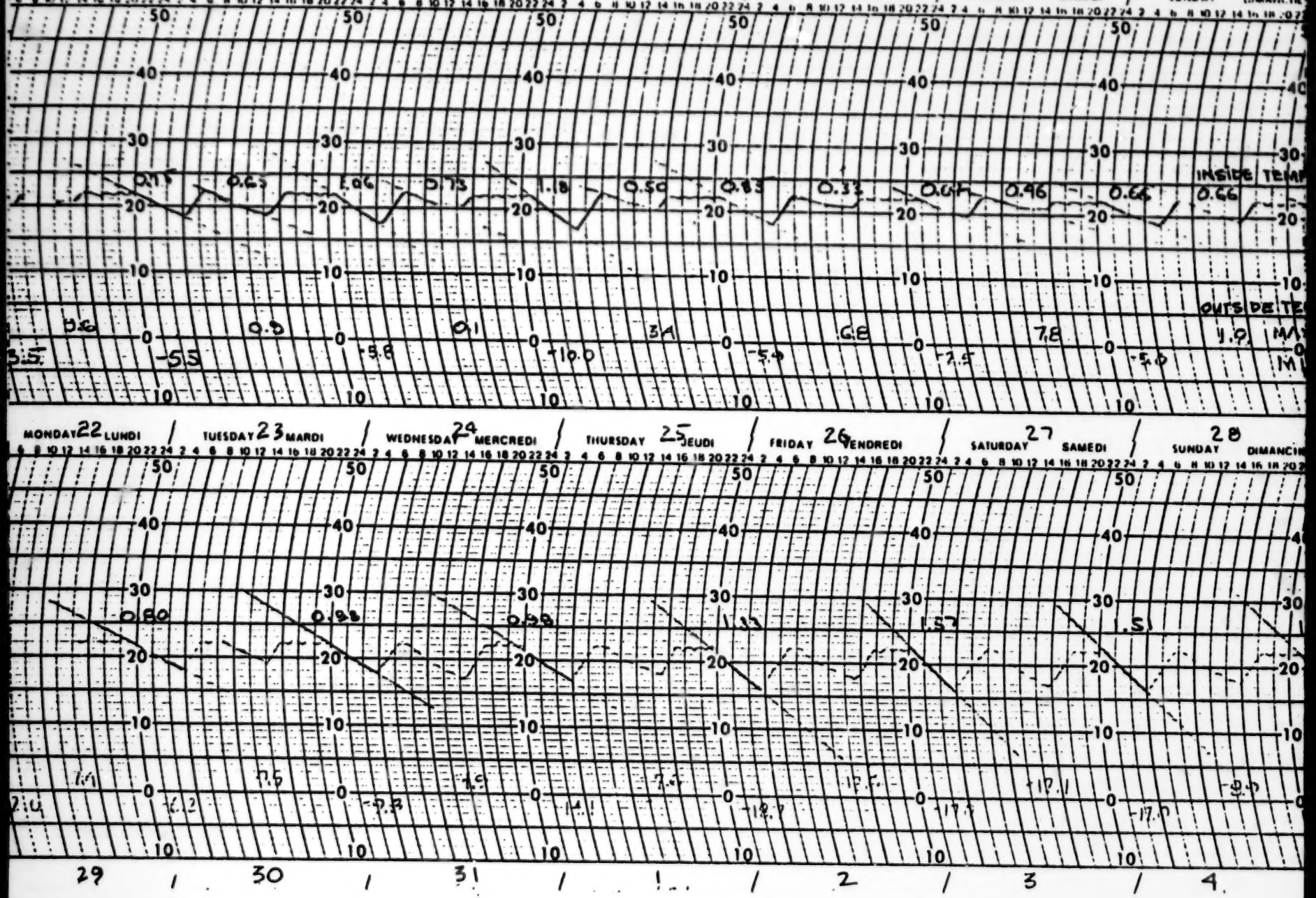

MONDAY LUNDI
TUESDAY MARDI
WEDNESDAY MERCREDI
THURSDAY JEUDI
FRIDAY VENDREDI
SATURDAY SAMEDI
SUNDAY DIMANCHE
INSIDE TEMP
OUTSIDE TEM
MAX
MIN
22
23
24
25
26
27
28
29
30
31
1
2
3
4

HALL RESIDENCE THERMOGRAPH RECORDS

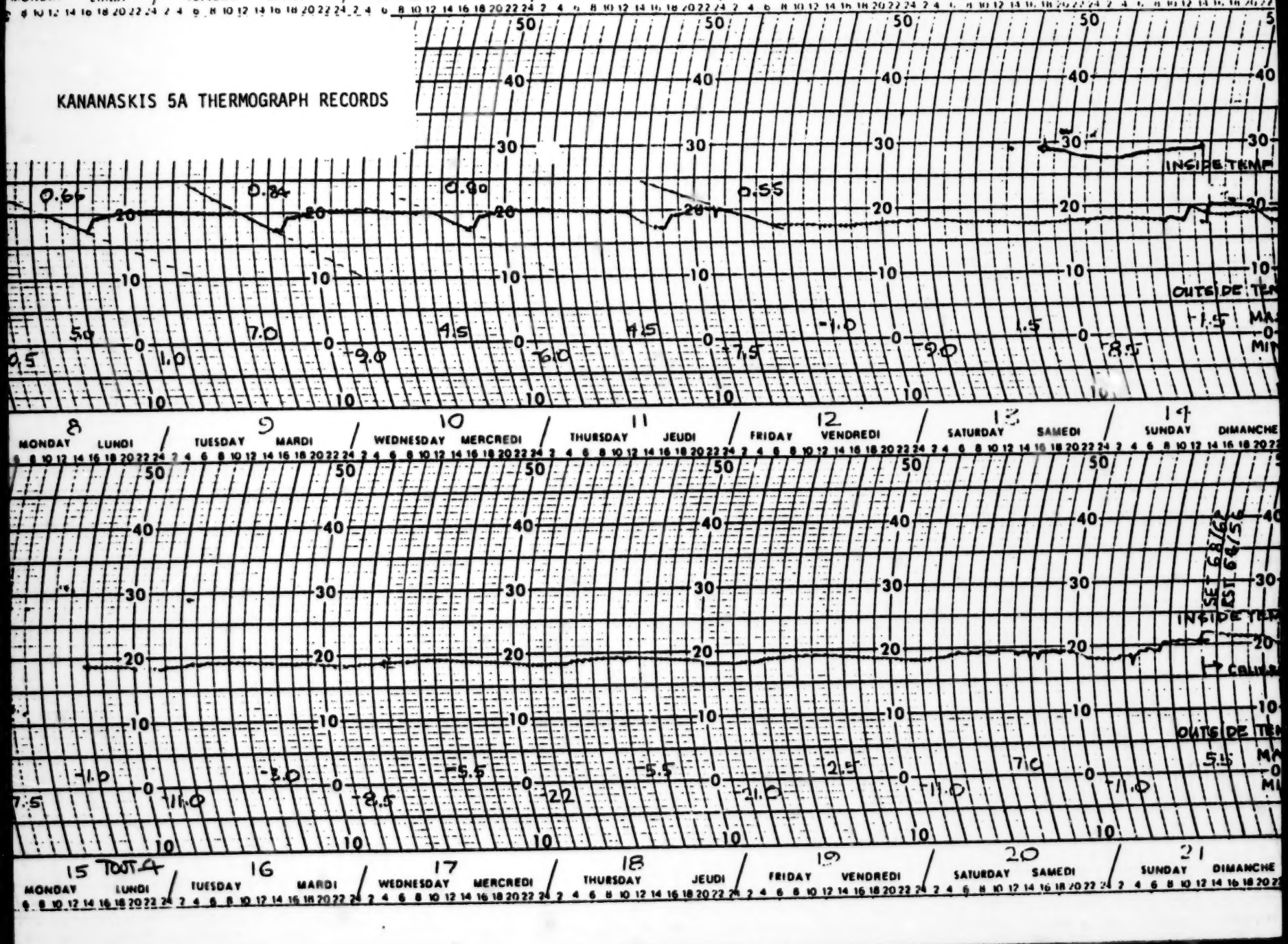


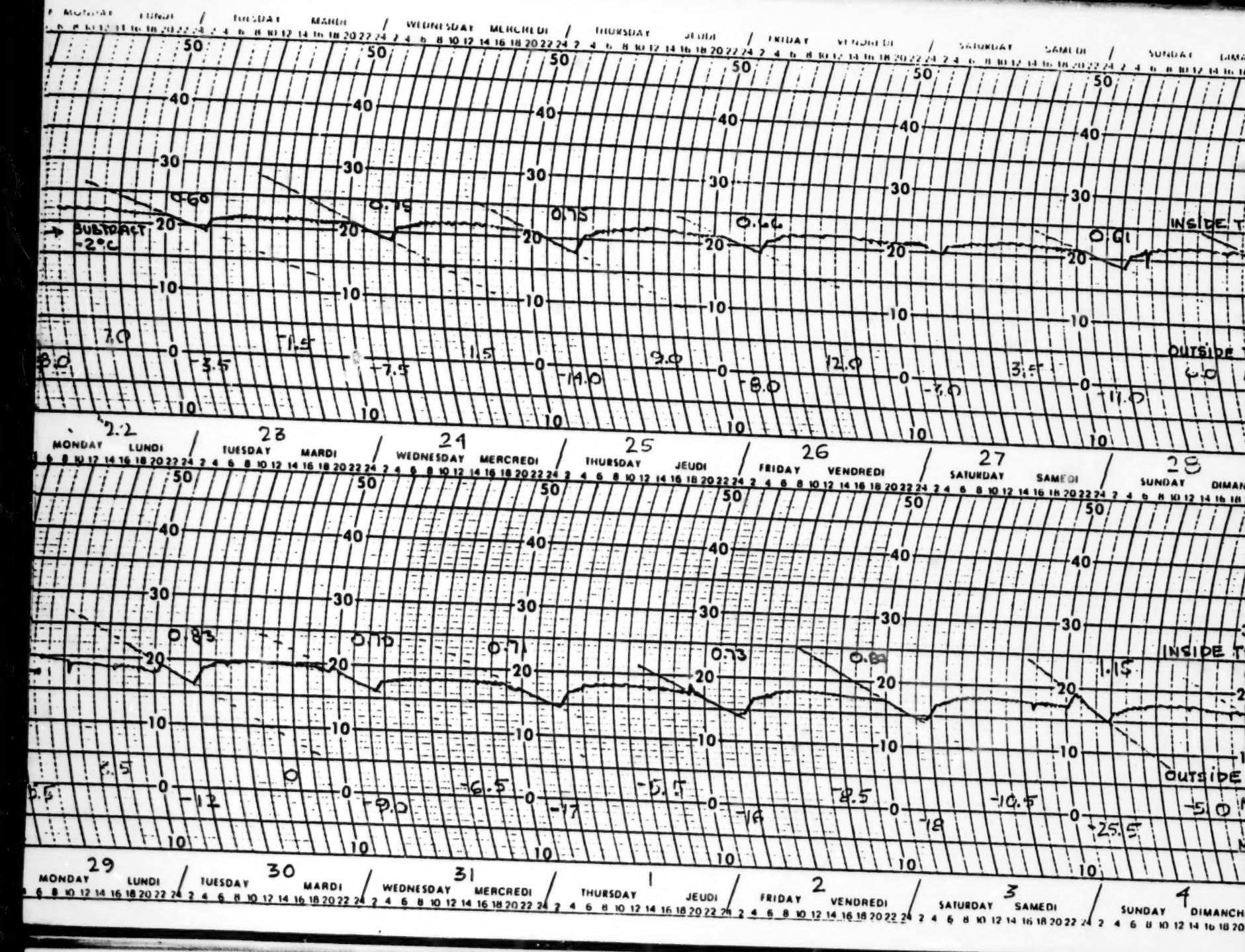

MONDAY LUNDI
TUESDAY MARDI
WEDNESDAY MERCREDI
THURSDAY JEUDI
FRIDAY VENDREDI
SATURDAY SAMEDI
SUNDAY DIMANCHE
22
23
24
25
26
29
30
31
1
2
3
4
INSIDE TEM
OUTSIDE TE
INSIDE TE
OUTSIDE TE


CAIRNS HOME THERMOGRAPH RECORDS
MONDAY LUNDI / TUESDAY MARDI / WEDNESDAY MERCREDI / THURSDAY JEUDI / FRIDAY VENDREDI / SATURDAY SAMEDI / SUNDAY DIMANCHE
INSIDE TEMP
OUTSIDE TEMP
Temp Decrease °C/hr
8 9 10 11 12 13 14
15 16 17 18 19 20 21

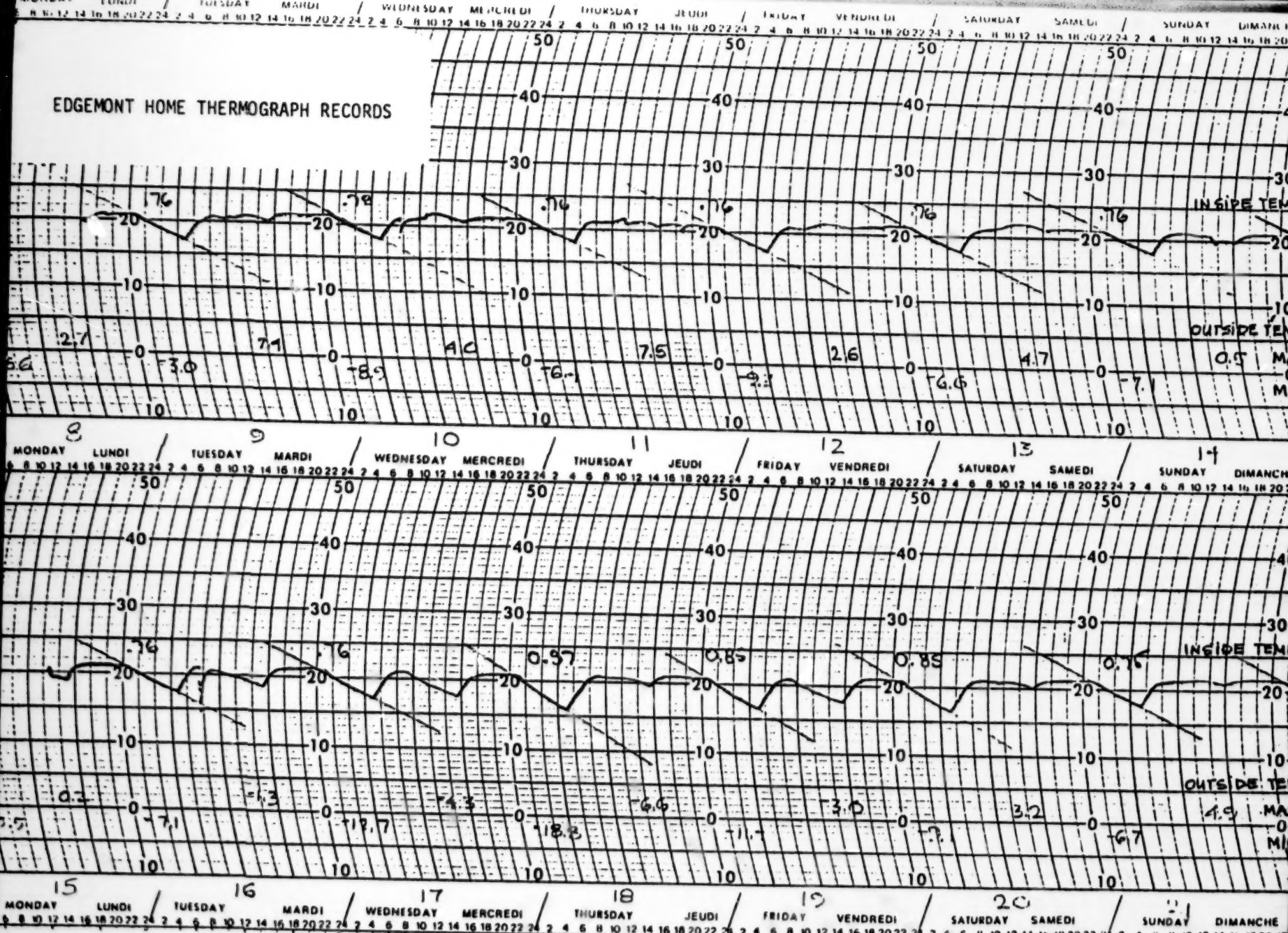

MONDAY LUNDI
TUESDAY MARDI
WEDNESDAY MERCREDI
THURSDAY JEUDI
FRIDAY VENDREDI
SATURDAY SAMEDI
SUNDAY DIMANCHE
INSIDE TEMP
OUTSIDE TEMP
MONDAY 22 LUNDI
TUESDAY 23 MARDI
WEDNESDAY 24 MERCREDI
THURSDAY 25 JEUDI
FRIDAY 26 VENDREDI
SATURDAY 27 SAMEDI
SUNDAY 28 DIMANCHE
29
30
31
1
2
3
4

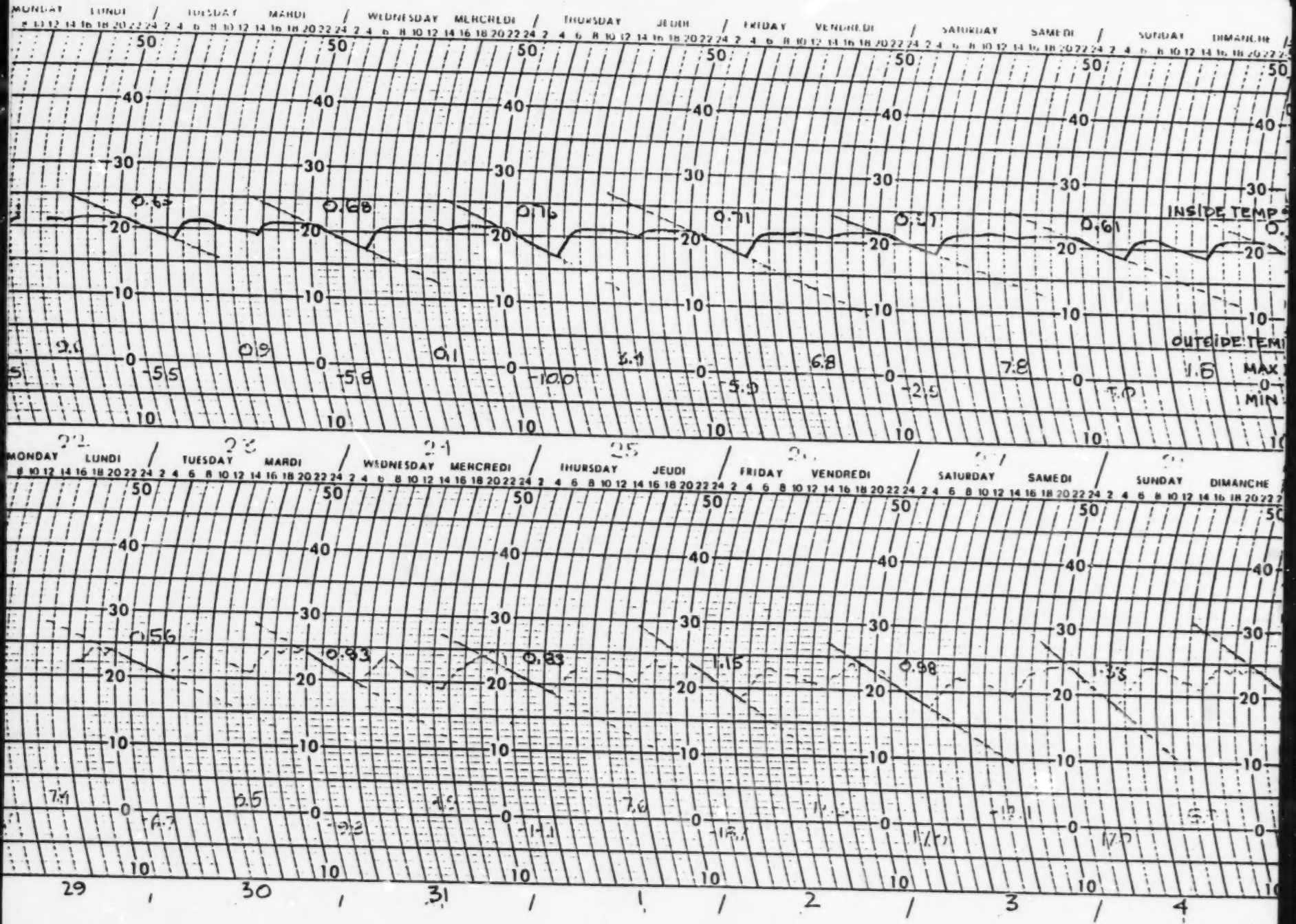
KANANASKIS 5A THERMOGRAPH RECORDS




MONDAY LUNDI
TUESDAY MARDI
WEDNESDAY MERCREDI
THURSDAY JEUDI
FRIDAY VENDREDI
SATURDAY SAMEDI
SUNDAY DIMANCHE
22
23
24
25
26
27
28
29
30
31
1
2
3
4
SUBTRACT -2°C
INSIDE T
OUTSIDE T
0.60
0.75
0.66
0.61
0.83
0.70
0.71
0.73
0.88
1.15
-1.5
-3.5
-7.5
-14.0
-8.0
-7.0
-11.0
-12
-9.0
-17
-16
-18
-25.5

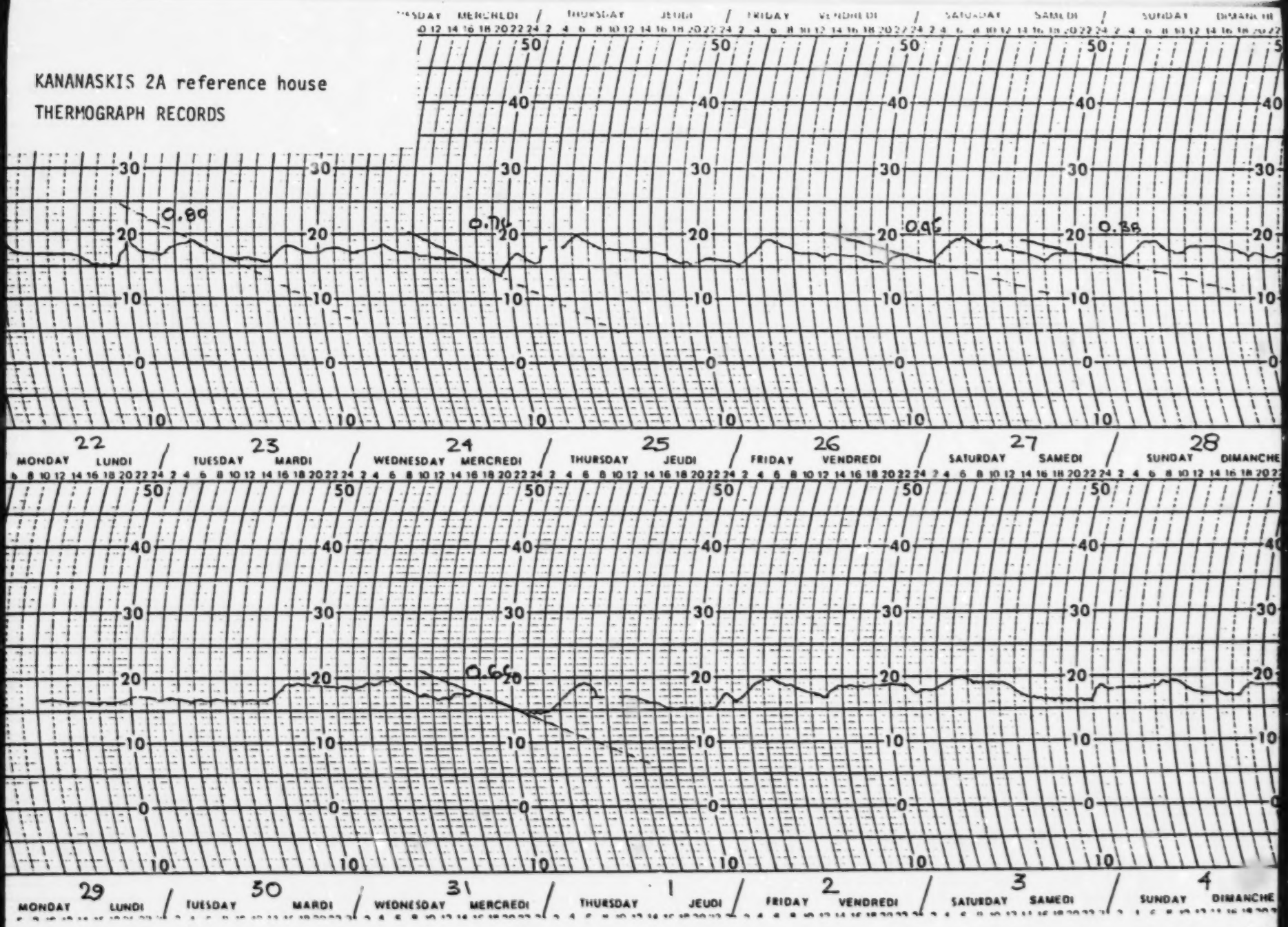
EDGEMONT HOME THERMOGRAPH RECORDS


MONDAY LUNDI TUESDAY MARDI WEDNESDAY MERCREDI THURSDAY JEUDI FRIDAY VENDREDI SATURDAY SAMEDI SUNDAY DIMANCHE
INSIDE TEM
OUTSIDE TE
8 9 10 11 12 13 14
15 16 17 18 19 20 21


MONDAY LUNDI / TUESDAY MARDI / WEDNESDAY MERCREDI / THURSDAY JEUDI / FRIDAY VENDREDI / SATURDAY SAMEDI / SUNDAY DIMANCHE
INSIDE TEMP
OUTSIDE TEMP
MAX
MIN
0.63
0.68
0.76
0.71
0.61
0.56
0.83
0.83
1.15
0.98
1.33
22
23
24
25
26
27
28
29
30
31
1
2
3
4

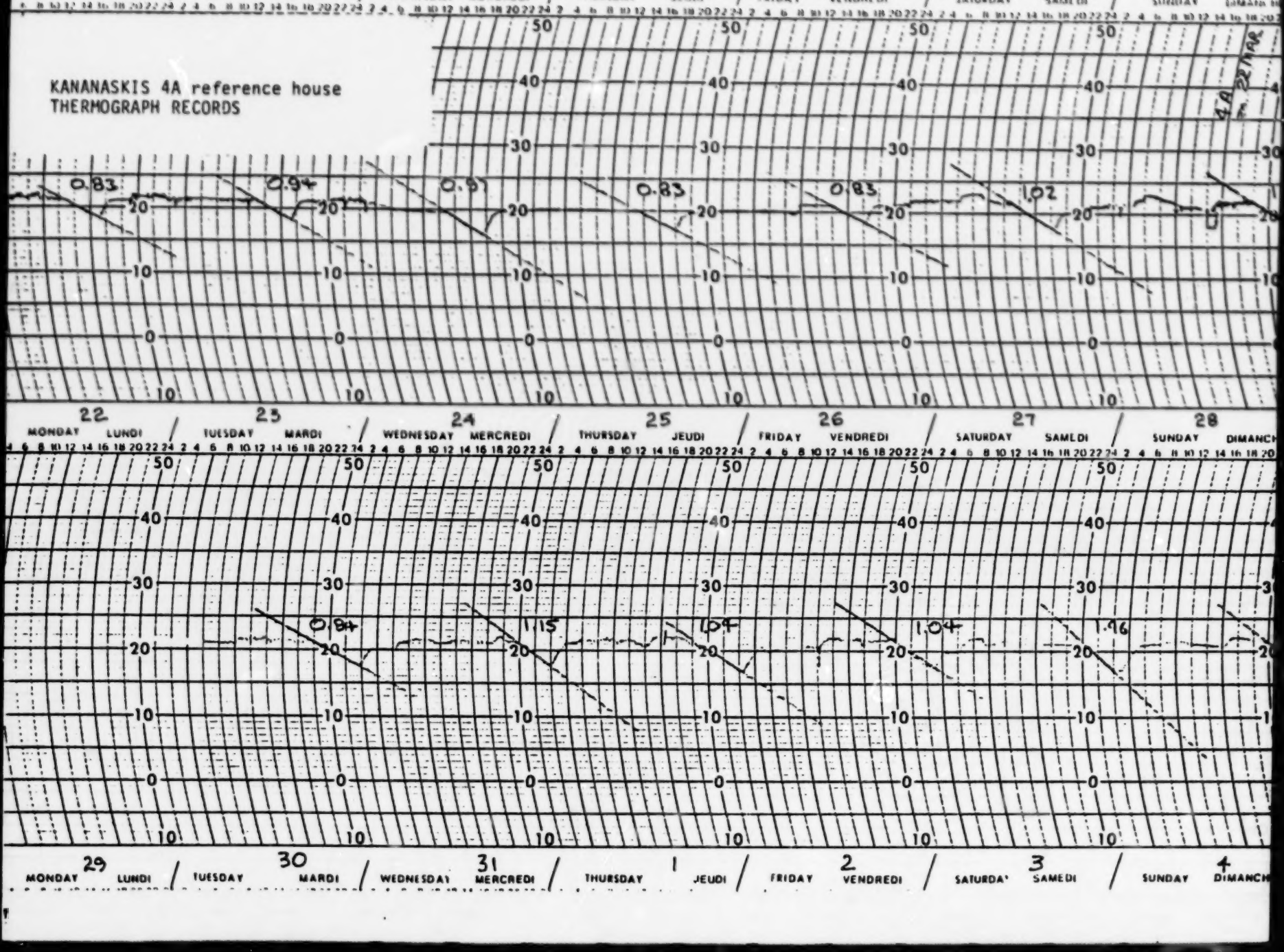
KANANASKIS 2A reference house

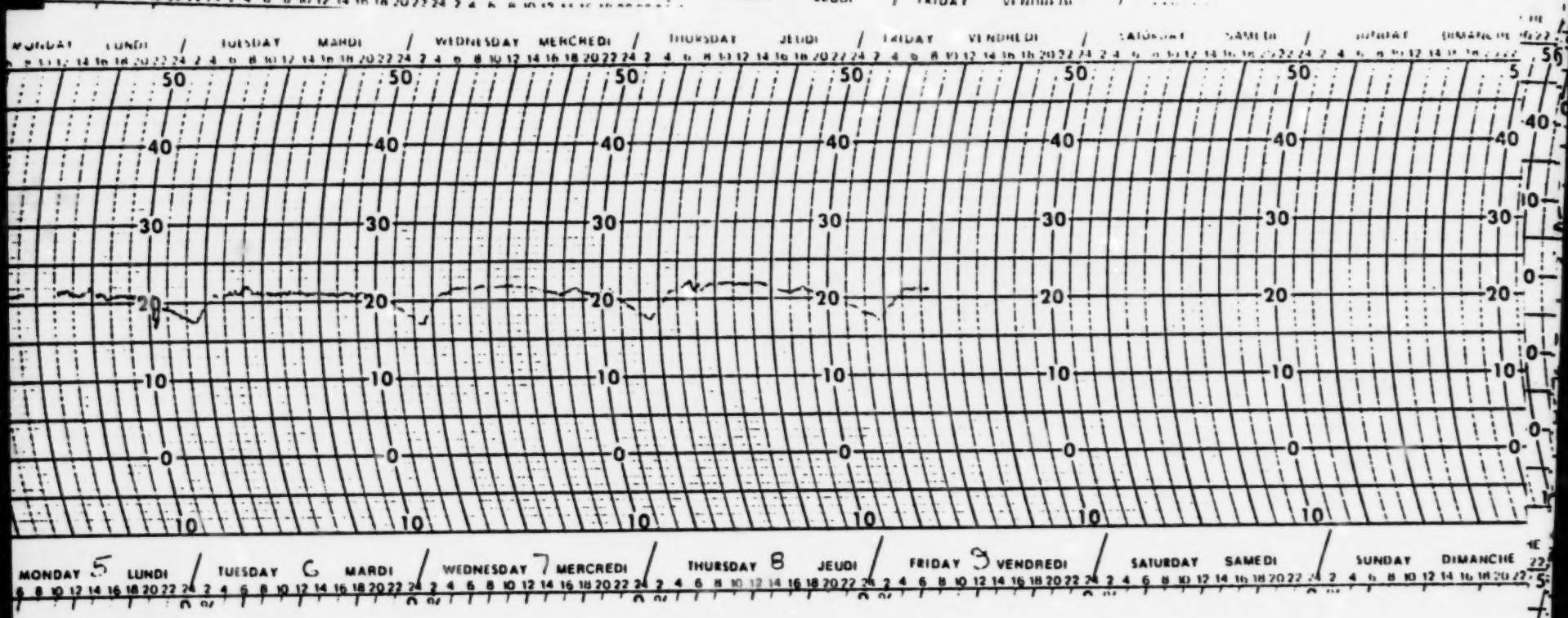
THERMOGRAPH RECORDS



MONDAY LUNDI
TUESDAY MARDI
WEDNESDAY MERCREDI
THURSDAY JEUDI
FRIDAY VENDREDI
SATURDAY SAMEDI
SUNDAY DIMANCHE
0.74
0.60
0.28
0.26
0.15
0.62
5
6
7
8
9
10
12
13
14
15
16
10
11

KANANASKIS 4A reference house
THERMOGRAPH RECORDS

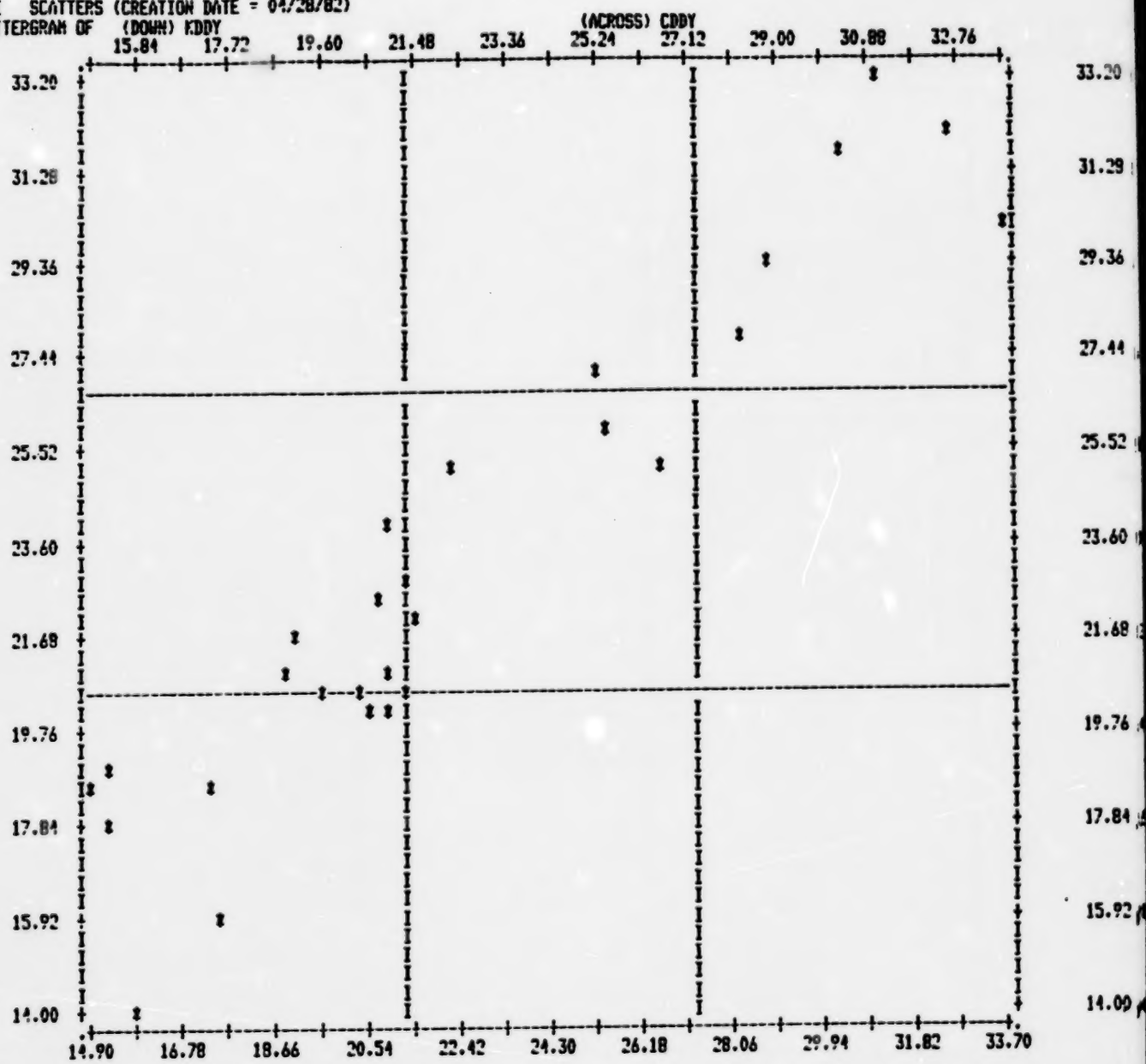



MONDAY LUNDI / TUESDAY MARDI / WEDNESDAY MERCREDI / THURSDAY JEUDI / FRIDAY VENDREDI / SATURDAY SAMEDI / SUNDAY DIMANCHE
50
40
30
20
10
0
10
MONDAY 5 LUNDI / TUESDAY 6 MARDI / WEDNESDAY 7 MERCREDI / THURSDAY 8 JEUDI / FRIDAY 9 VENDREDI / SATURDAY SAMEDI / SUNDAY DIMANCHE

APPENDIX C

Regression Analyses

FILE SCATTERS (CREATION DATE = 04/28/82)

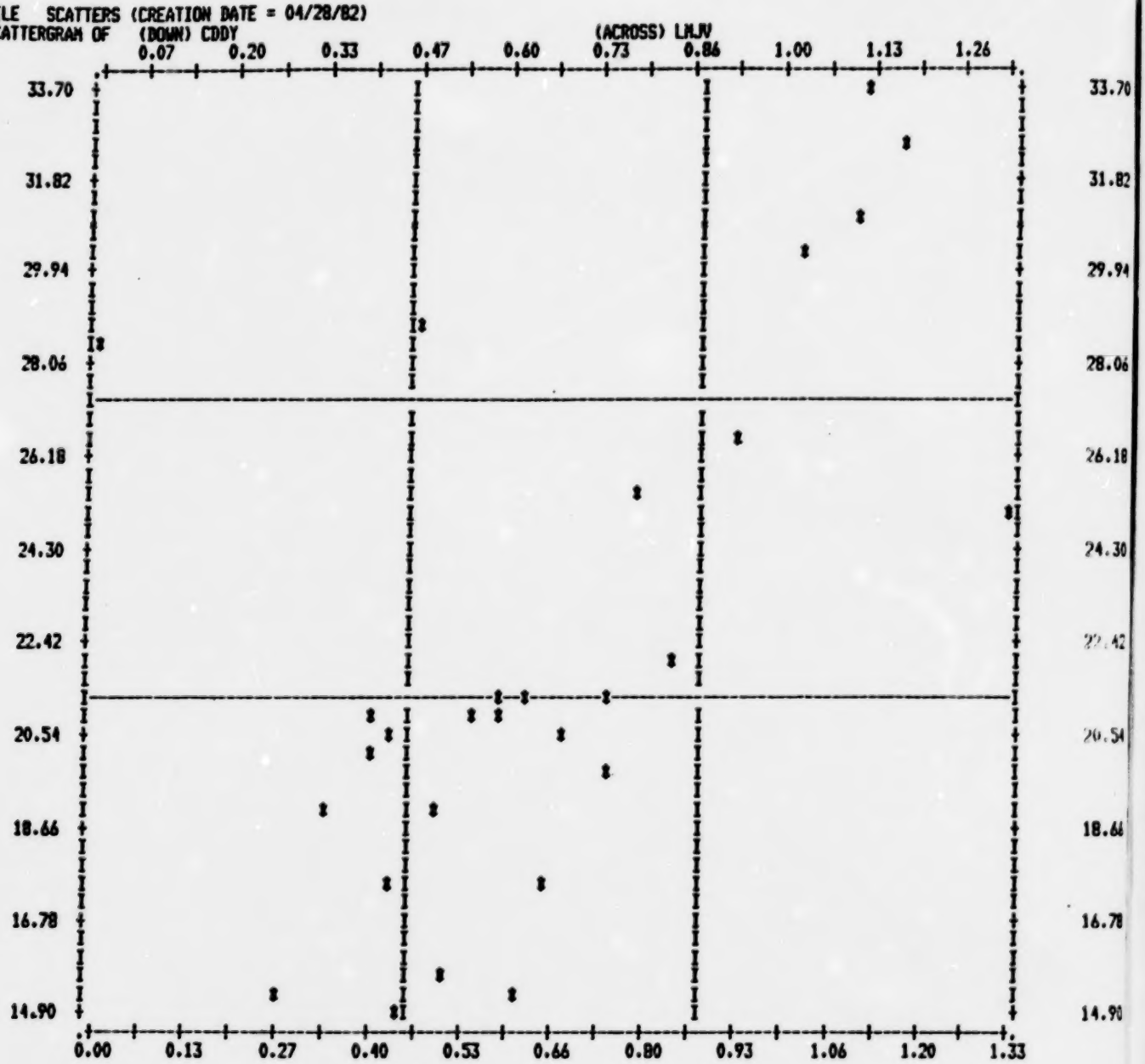


LINEAR REGRESSION OF CALGARY DEGREE DAYS VS KANANASKIS DEGREE DAYS FOR THE STUDY PERIOD

STATISTICS..

CORRELATION (R)-	0.94372	R SQUARED -	0.89062	SIGNIFICANCE -	0.00000
STD ERR OF EST -	1.68060	INTERCEPT (A) -	3.61120	SLOPE (B) -	0.87414
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

FILE SCATTERS (CREATION DATE = 04/28/82)
SCATTERGRAM OF (DOWN) CDDY (ACROSS) LMJV

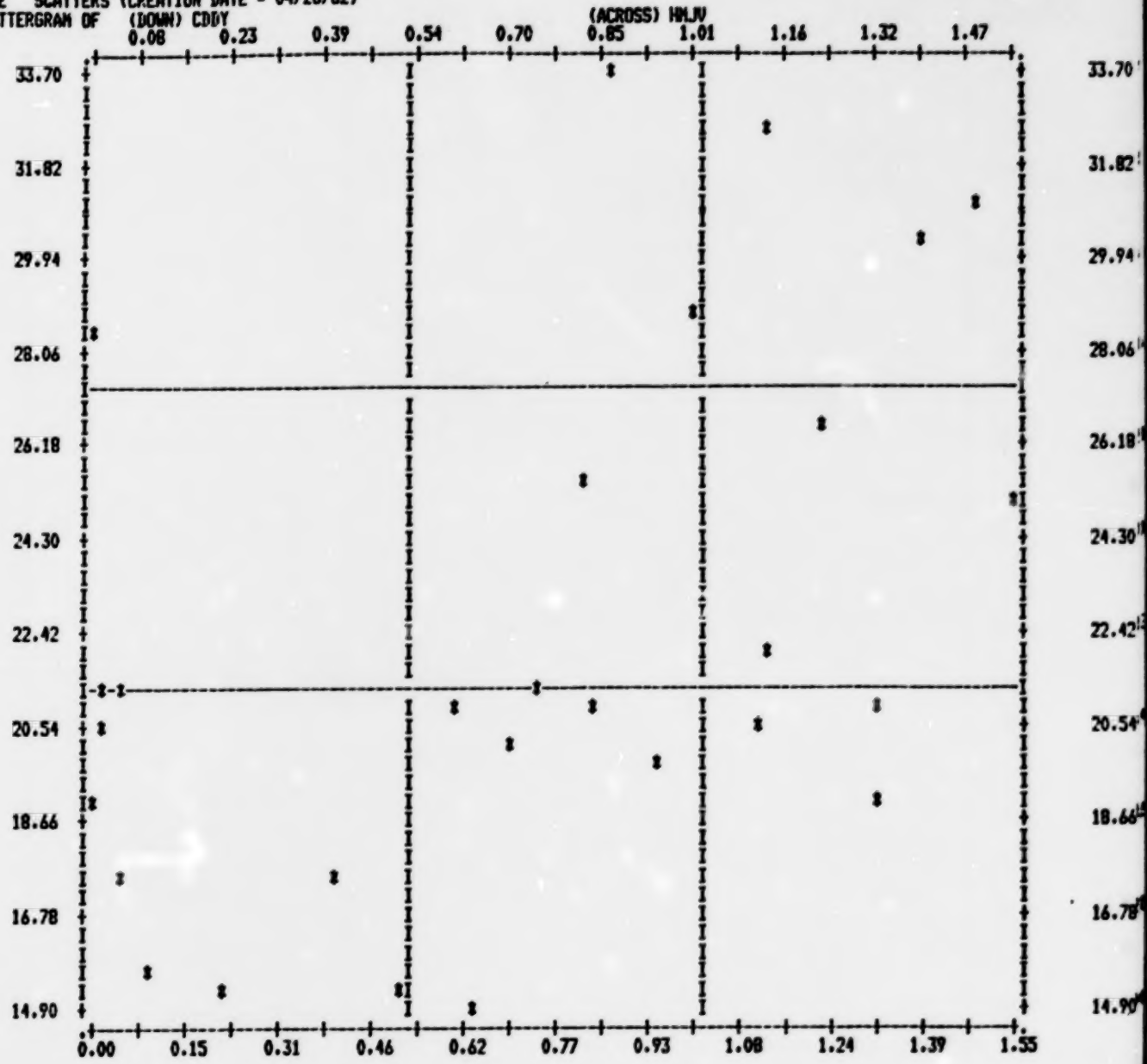


LINEAR REGRESSION OF LIVINGSTONE MEGAJOULES PER VOLUME VS CALGARY DEGREE DAYS

STATISTICS..

CORRELATION (R)-	0.57661	R SQUARED -	0.33248	SIGNIFICANCE -	0.00132
STD ERR OF EST -	4.48212	INTERCEPT (A) -	15.73814	SLOPE (B) -	10.18289
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

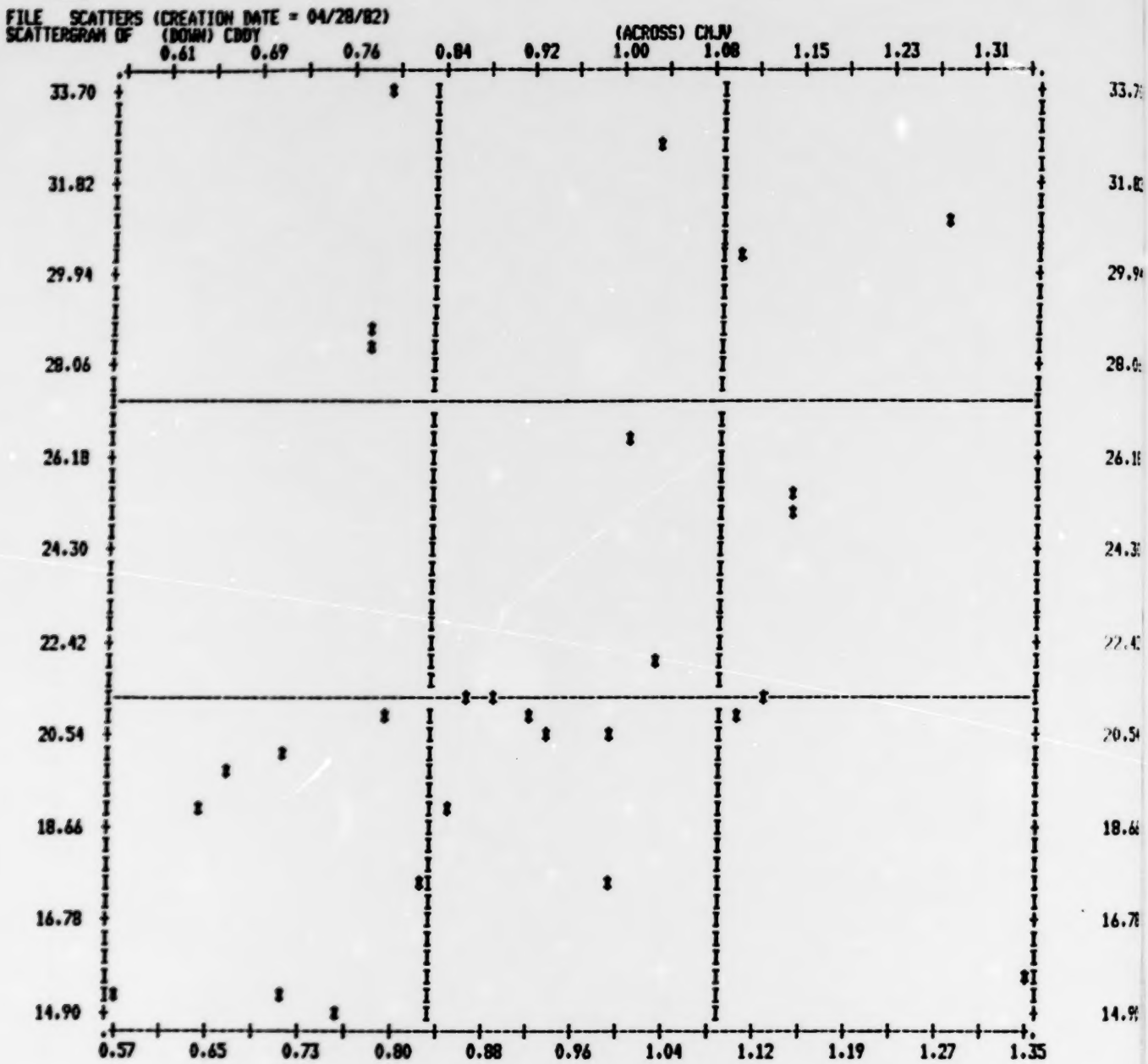
FILE SCATTERS (CREATION DATE = 04/28/82)



LINEAR REGRESSION OF HALL MEGAJOULES PER VOLUME VS CALGARY DEGREE DAYS

STATISTICS..

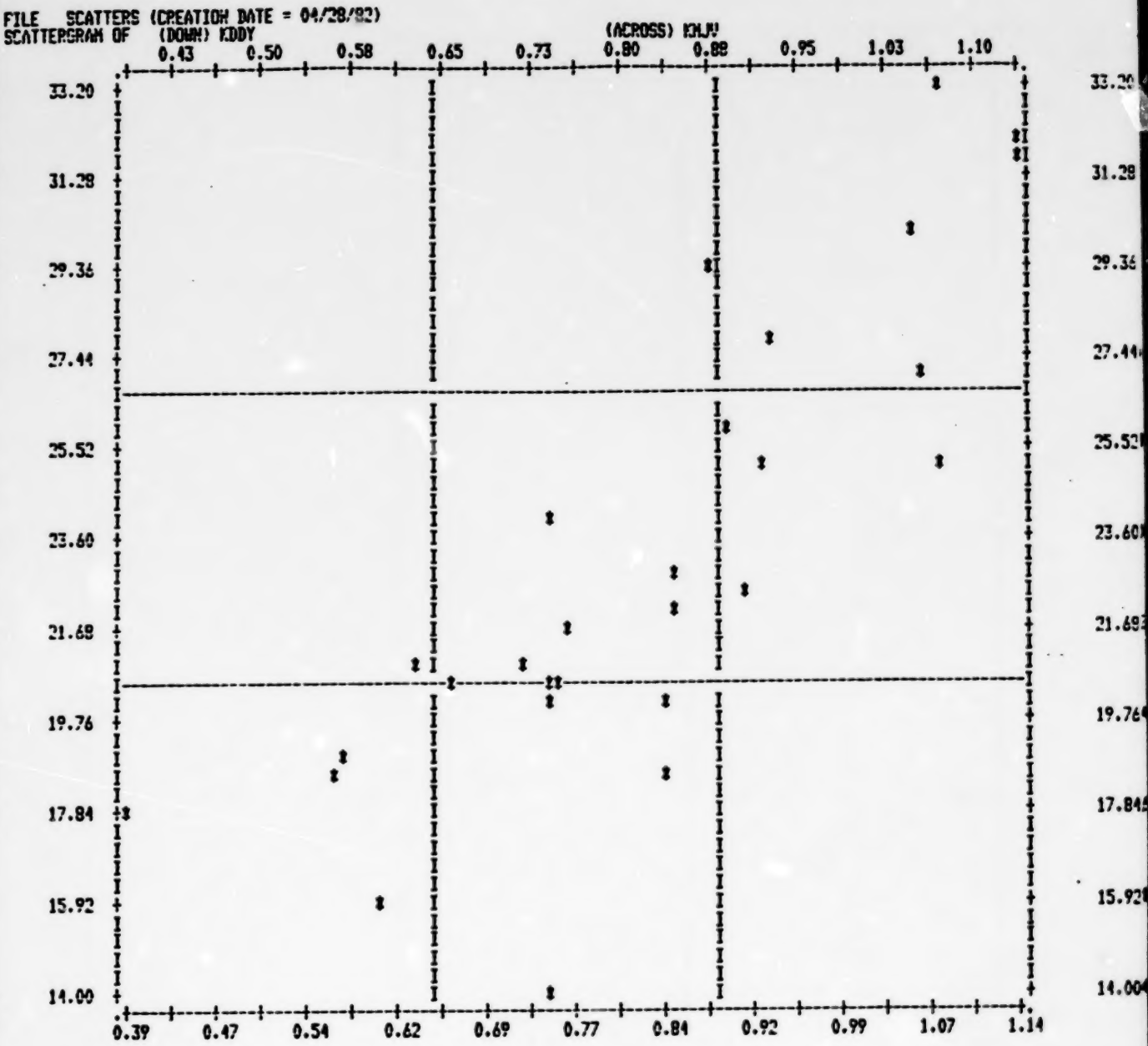
CORRELATION (R)-	0.48160	R SQUARED -	0.23194	SIGNIFICANCE -	0.00946
STD ERR OF EST -	4.80784	INTERCEPT (A) -	18.74472	SLOPE (B) -	5.03717
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0



LINEAR REGRESSION OF CAIRNS MEGAJOULES PER VOLUME VS CALGARY DEGREE DAYS

STATISTICS..

CORRELATION (R)-	0.30666	R SQUARED -	0.09404	SIGNIFICANCE -	0.11246
STD ERR OF EST -	5.22162	INTERCEPT (A) -	14.58883	SLOPE (B) -	8.43521
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

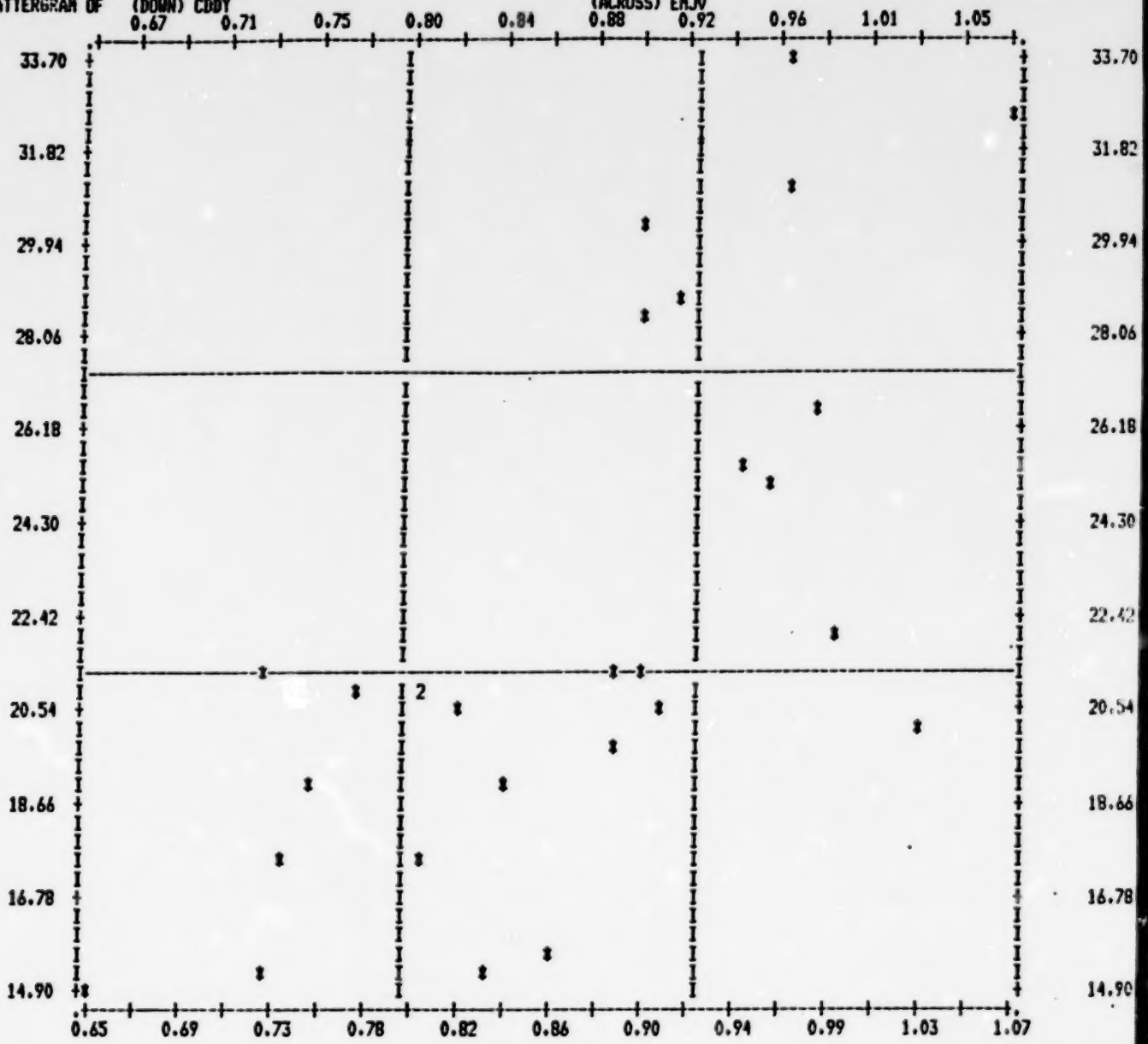


LINEAR REGRESSION OF KANANASKIS MEGAJOULES PER VOLUME VS KANANASKIS DEGREE DAYS

STATISTICS..

CORRELATION (R)-	0.82397	R SQUARED -	0.67893	SIGNIFICANCE -	0.00000
STD ERR OF EST -	2.87928	INTERCEPT (A) -	5.14220	SLOPE (B) -	21.89751
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

FILE SCATTERS (CREATION DATE = 04/28/82)
SCATTERGRAM OF (DOWN) CDDY (ACROSS) EMJV

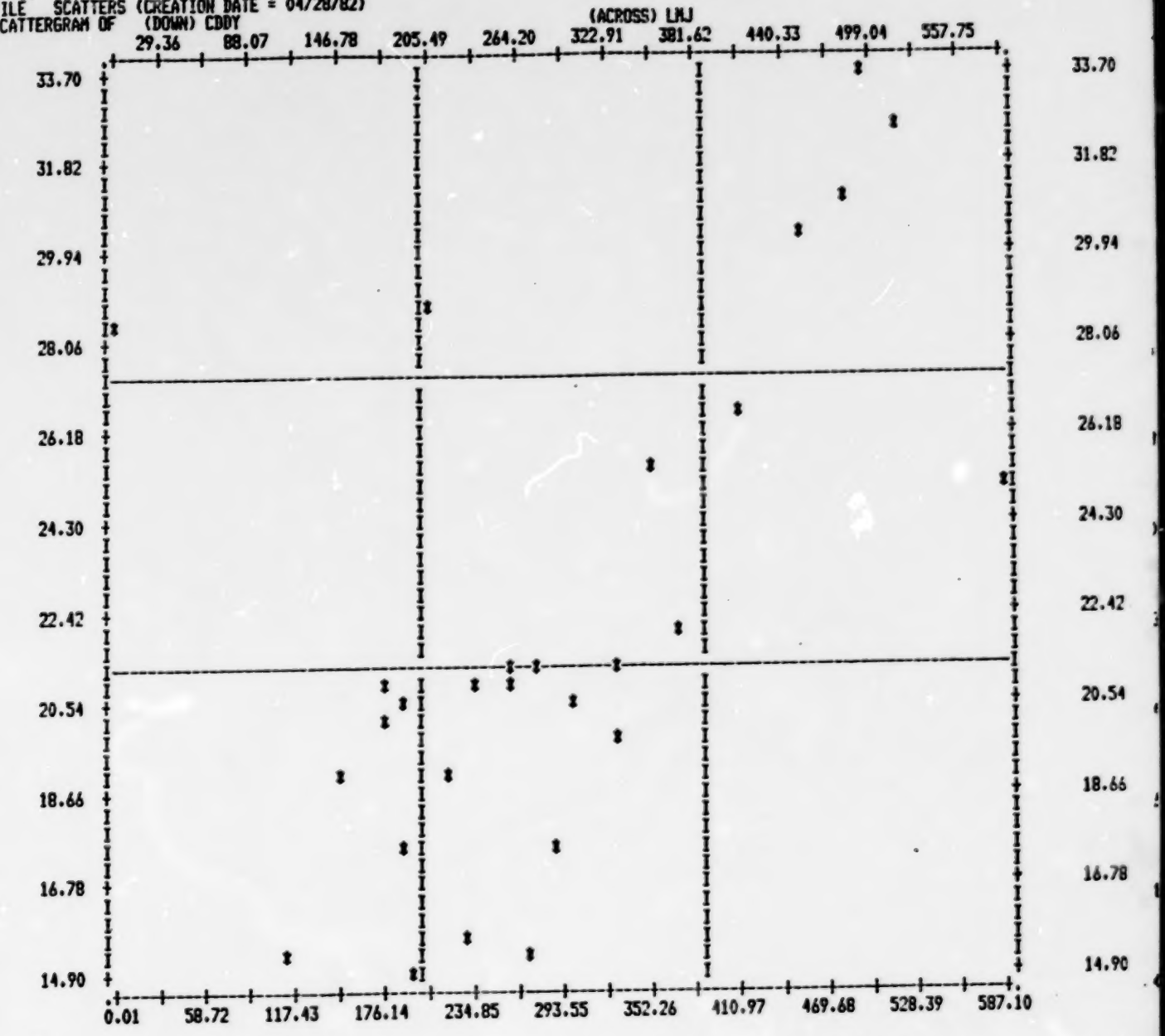


LINEAR REGRESSION OF EDGEMONT MEGAJOULES PER VOLUME VS CALGARY DEGREE DAYS

STATISTICS..

CORRELATION (R)-	0.68984	R SQUARED -	0.47588	SIGNIFICANCE -	0.00005
STD ERR OF EST -	3.97160	INTERCEPT (A) -	-9.18685	SLOPE (B) -	36.28057
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

ILE SCATTERS (CREATION DATE = 04/28/82)
CATTERGRAM OF (DOWN) CDDY

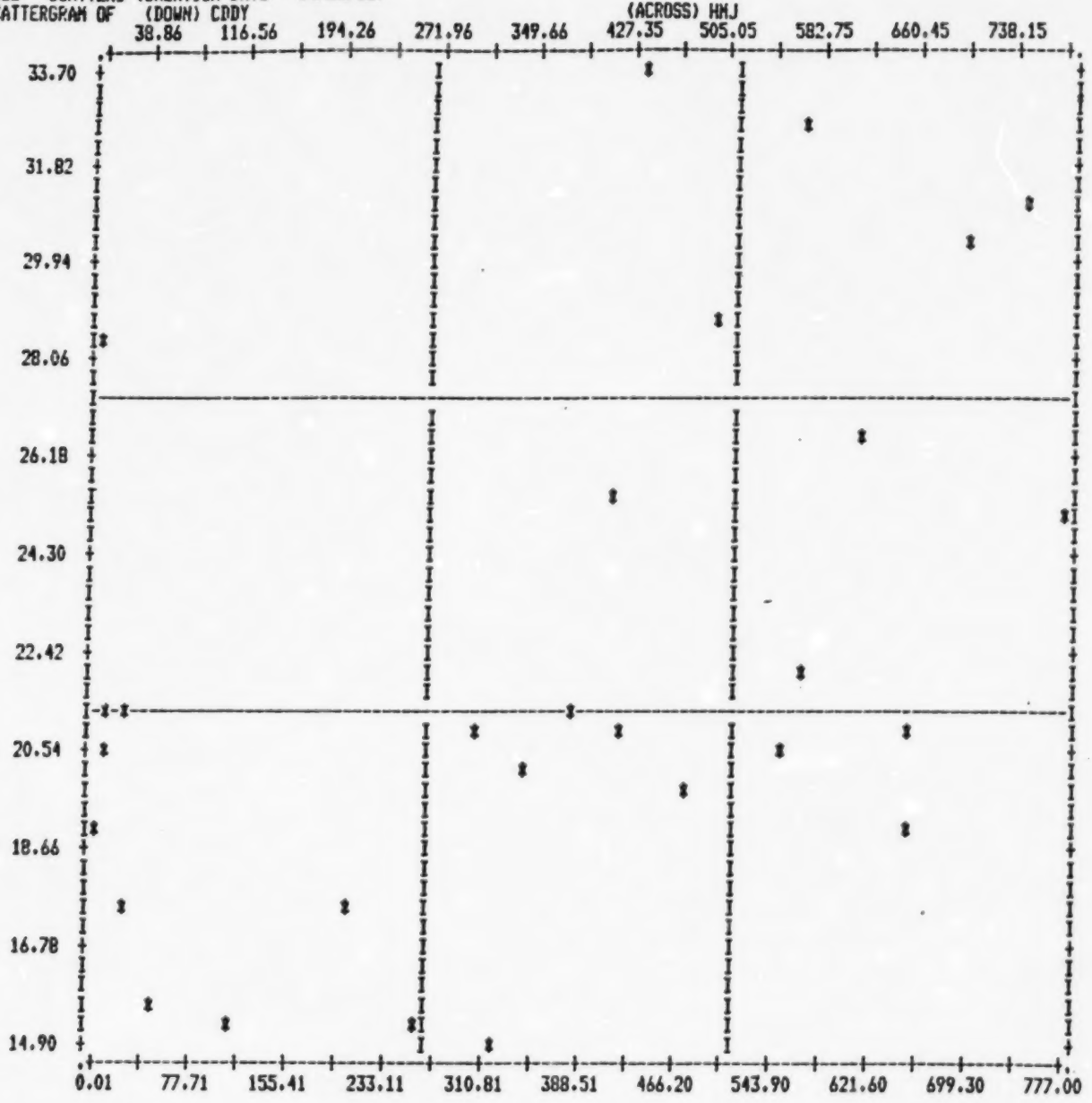


LINEAR REGRESSION OF LIVINGSTONE MEGAJOULES VS CALGARY DEGREE DAYS

STATISTICS..

CORRELATION (R)-	0.57521	R SQUARED -	0.33086	SIGNIFICANCE -	0.00136
STD ERR OF EST -	4.48755	INTERCEPT (A) -	15.76083	SLOPE (B) -	0.02301
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

FILE SCATTERS (CREATION DATE = 04/28/82)
SCATTERGRAM OF (DOWN) CDDY (ACROSS) HMJ

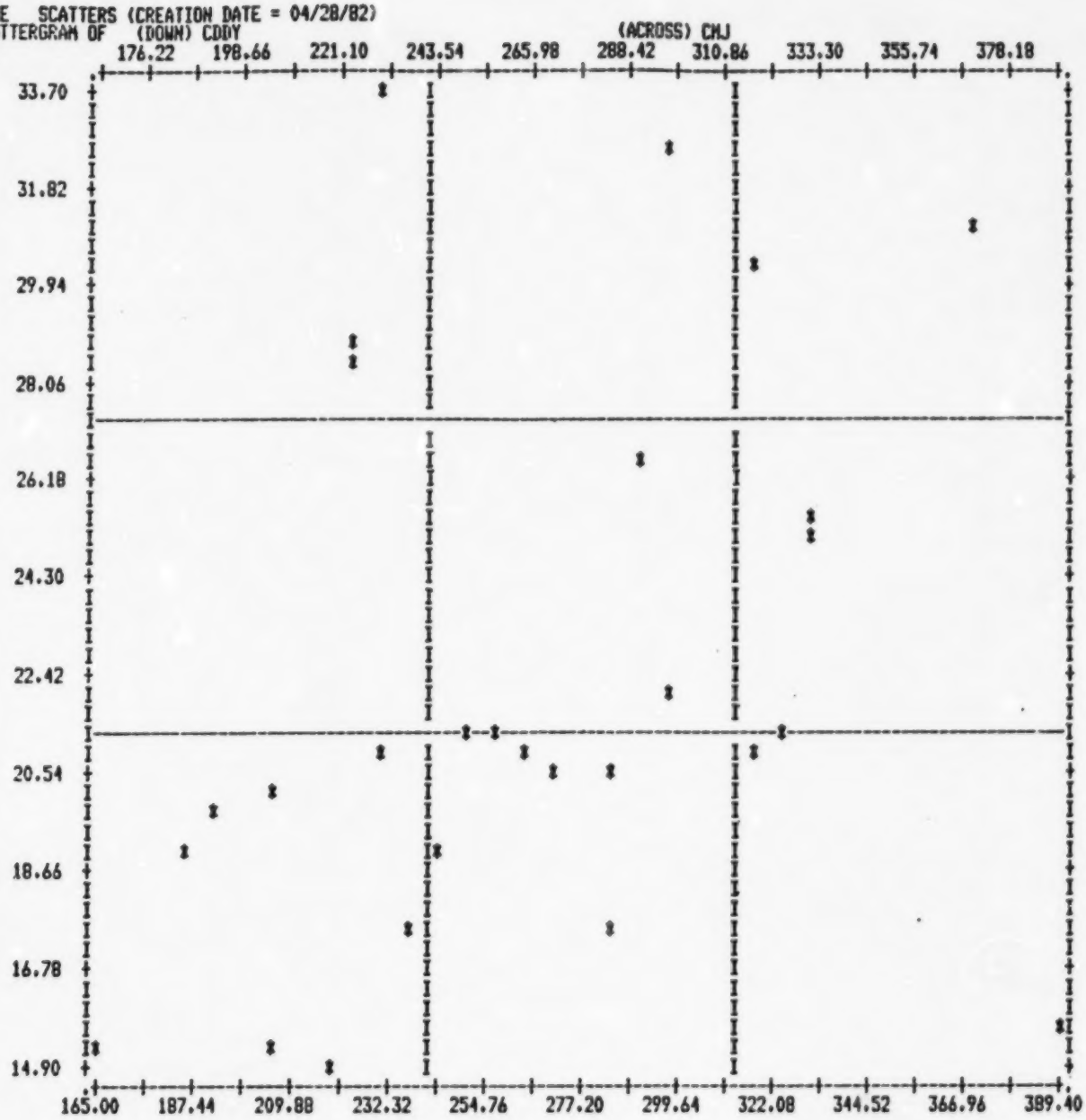


LINEAR REGRESSION OF HALL MEGAJOULES VS CALGARY DEGREE DAYS

STATISTICS..

CORRELATION (R)-	0.48003	R SQUARED -	0.23043	SIGNIFICANCE -	0.00973
STD ERR OF EST -	4.81255	INTERCEPT (A) -	18.74991	SLOPE (B) -	0.01005
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

FILE SCATTERS (CREATION DATE = 04/28/82)
SCATTERGRAM OF (DOWN) CDDY (ACROSS) CMJ

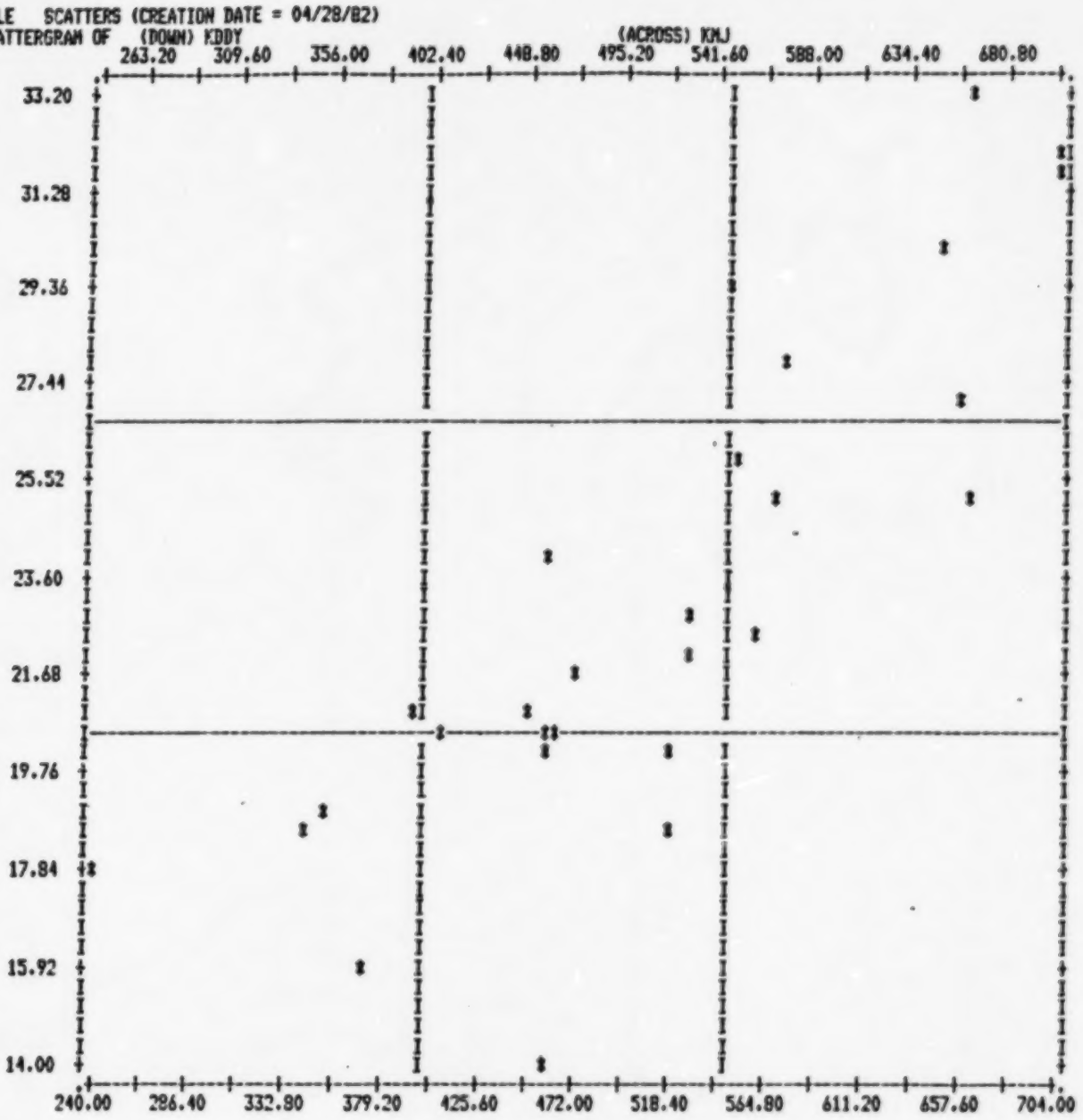


LINEAR REGRESSION OF CAIRNS MEGAJOULES VS CALGARY DEGREE DAYS

STATISTICS..

CORRELATION (R)-	0.30898	R SQUARED -	0.09547	SIGNIFICANCE -	0.10963
STD ERR OF EST -	5.21750	INTERCEPT (A) -	14.51871	SLOPE (B) -	0.02956
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

FILE SCATTERS (CREATION DATE = 04/28/82)

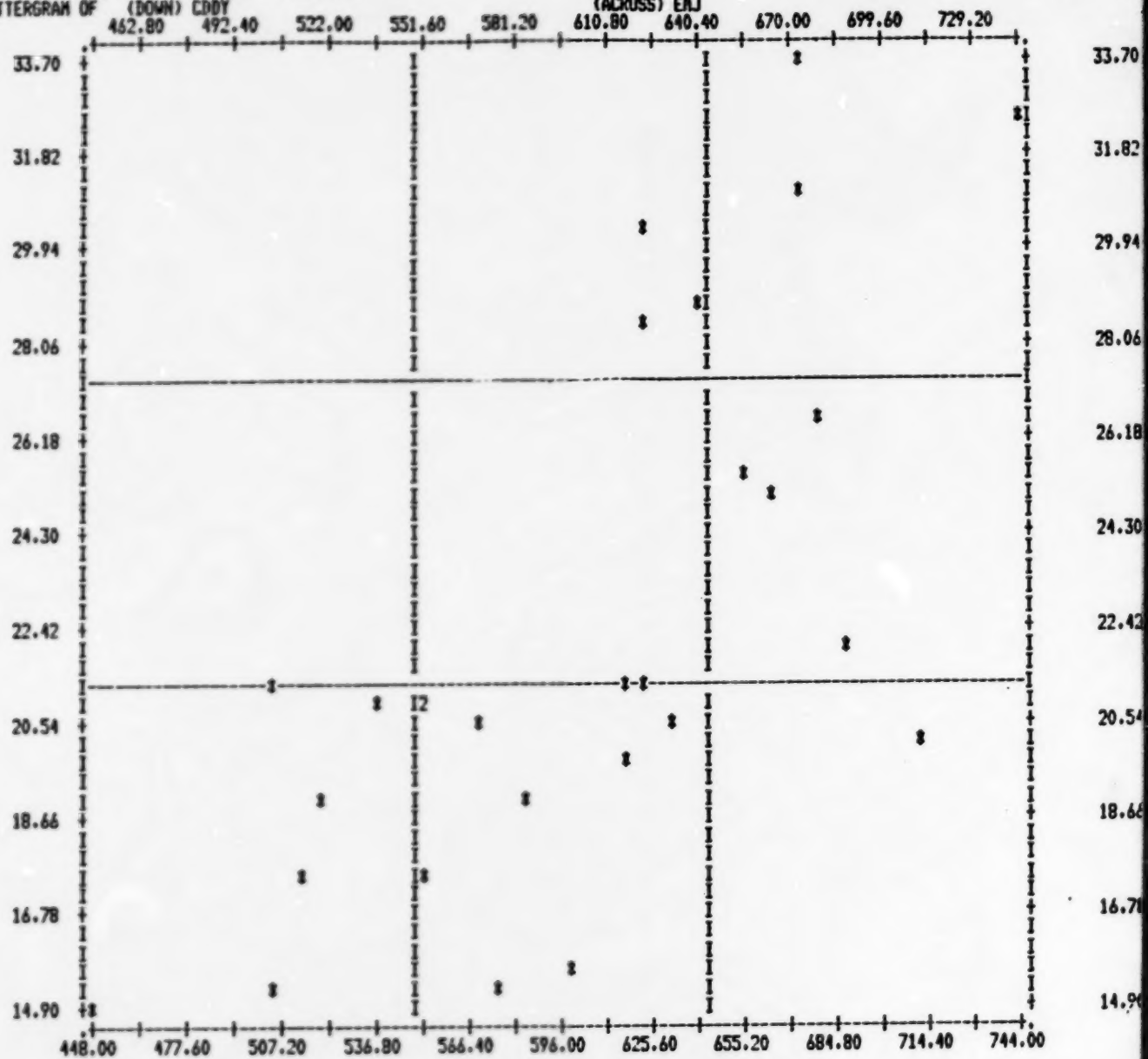


LINEAR REGRESSION OF KANANASKIS MEGAJOULES VS KANANASKIS DEGREE DAYS

STATISTICS..

CORRELATION (R)-	0.82453	R SQUARED -	0.67984	SIGNIFICANCE -	0.00000
STD ERR OF EST -	2.87521	INTERCEPT (A) -	5.19124	SLOPE (B) -	0.03531
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

FILE SCATTERS (CREATION DATE = 04/28/82)
SCATTERGRAM OF (DOWN) CDDY (ACROSS) ENJ

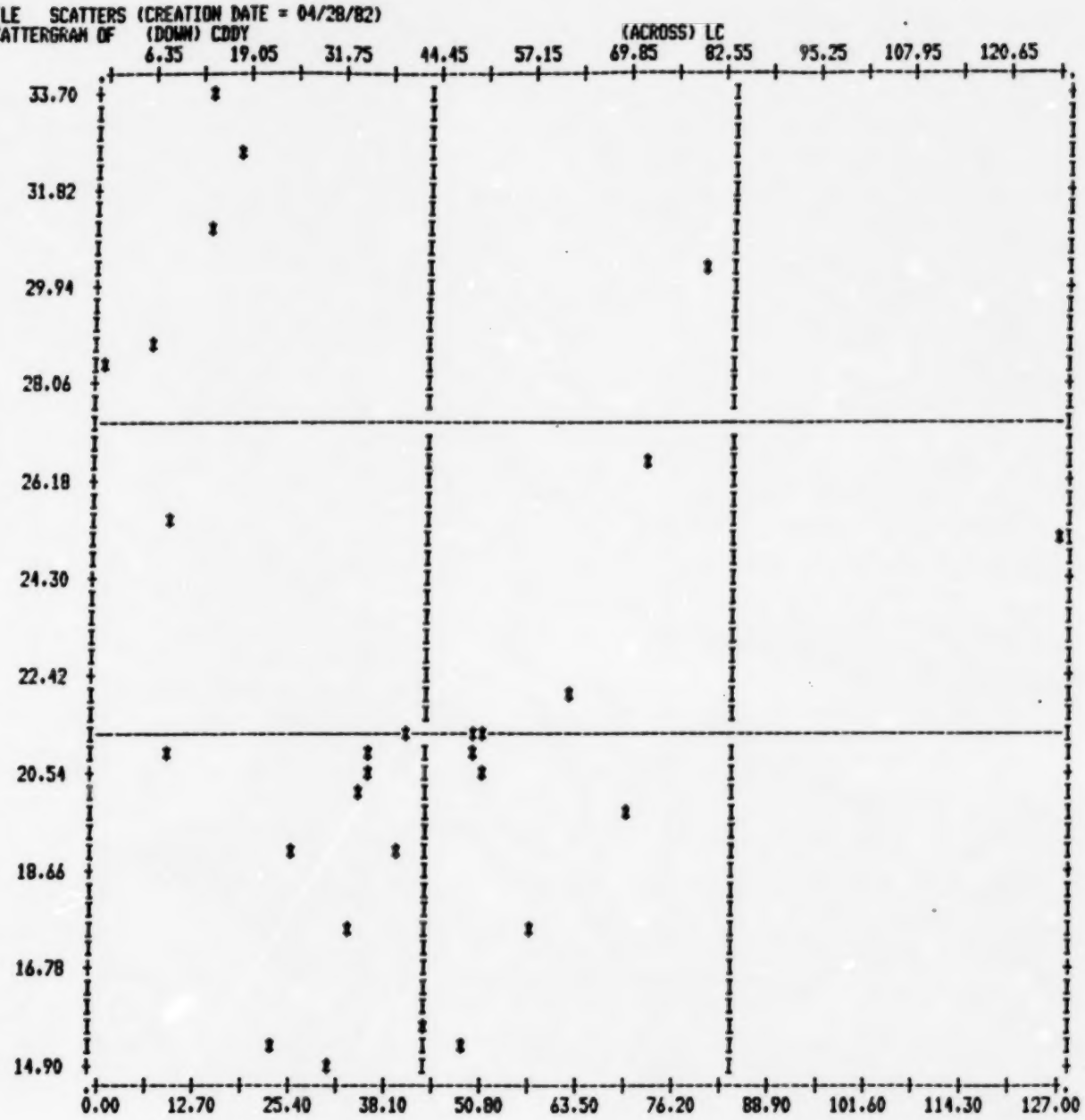


LINEAR REGRESSION OF EDGEMONT MEGAJOULES VS CALGARY DEGREE DAYS

STATISTICS..

CORRELATION (R)-	0.68889	R SQUARED -	0.47457	SIGNIFICANCE -	0.00005
STD ERR OF EST -	3.97658	INTERCEPT (A) -	-8.86541	SLOPE (B) -	0.05183
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

FILE SCATTERS (CREATION DATE = 04/28/82)
SCATTERGRAM OF (DOWN) CDDY (ACROSS) LC

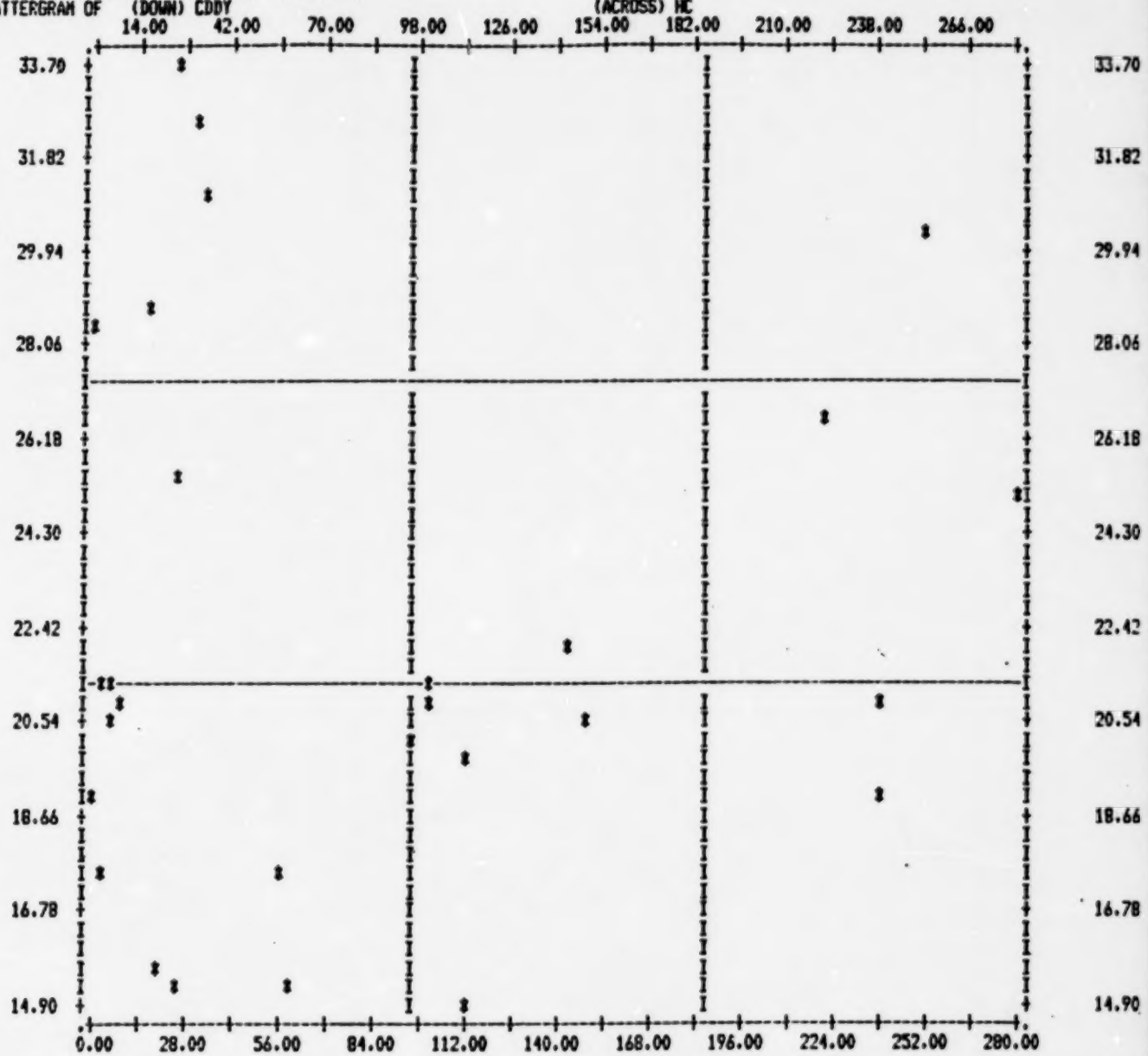


LINEAR REGRESSION OF LIVINGSTONE FURNACE CYCLES VS CALGARY DEGREE DAYS

STATISTICS..

CORRELATION (R)-	-0.14045	R SQUARED -	0.01973	SIGNIFICANCE -	0.47594
STD ERR OF EST -	5.43156	INTERCEPT (A) -	23.49512	SLOPE (B) -	-0.02802
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

FILE SCATTERS (CREATION DATE = 04/28/82)
SCATTERGRAM OF (DOWN) CDDY (ACROSS) HC

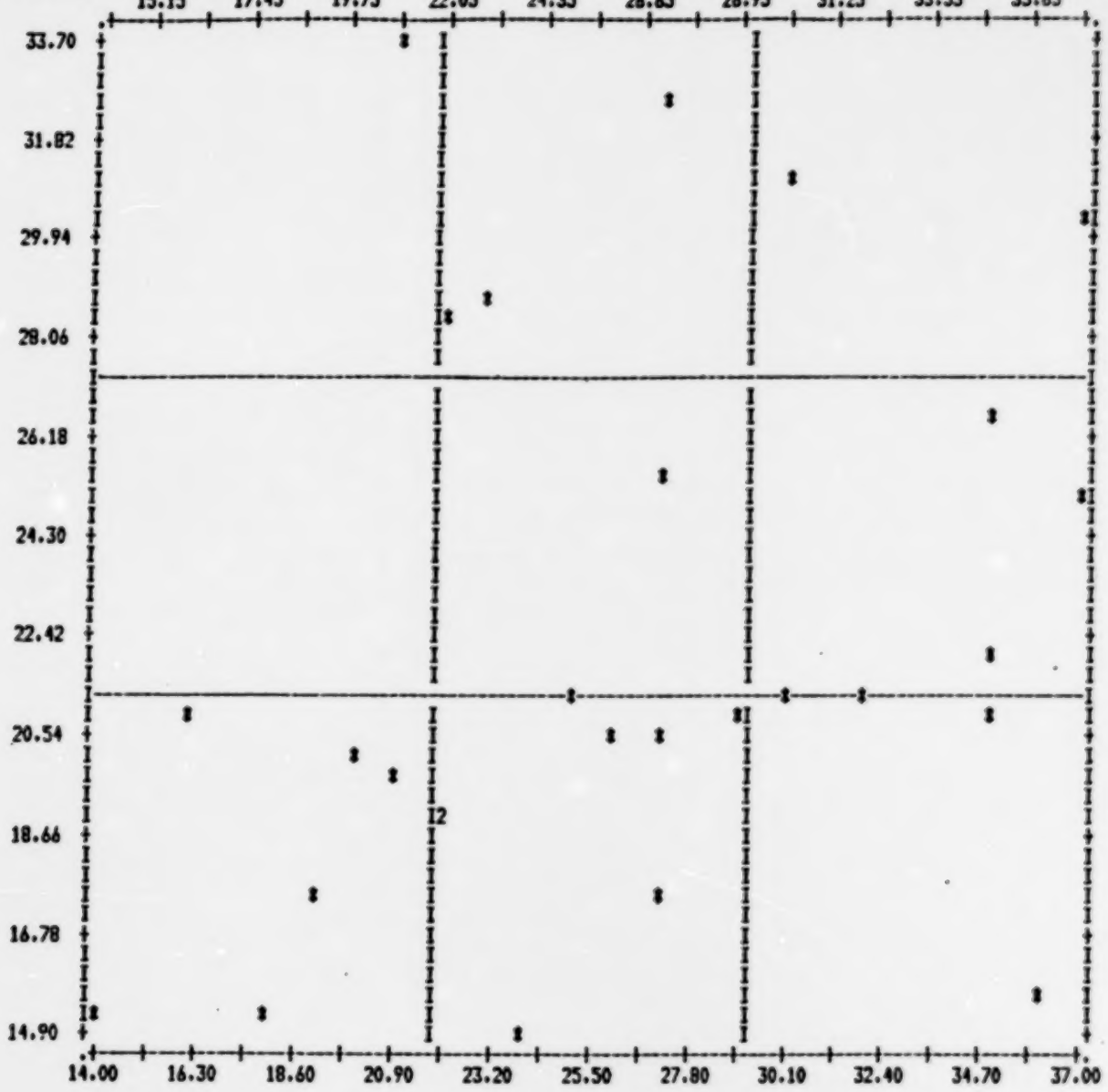


LINEAR REGRESSION OF HALL FURNACE CYCLES VS CALGARY DEGREE DAYS

STATISTICS..

CORRELATION (R)-	0.06158	R SQUARED -	0.00379	SIGNIFICANCE -	0.75557
STD ERR OF EST -	5.47553	INTERCEPT (A) -	22.05035	SLOPE (B) -	0.00373
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

FILE SCATTERS (CREATION DATE = 04/28/82)
SCATTERGRAM OF (DOWN) CDDY (ACROSS) CC

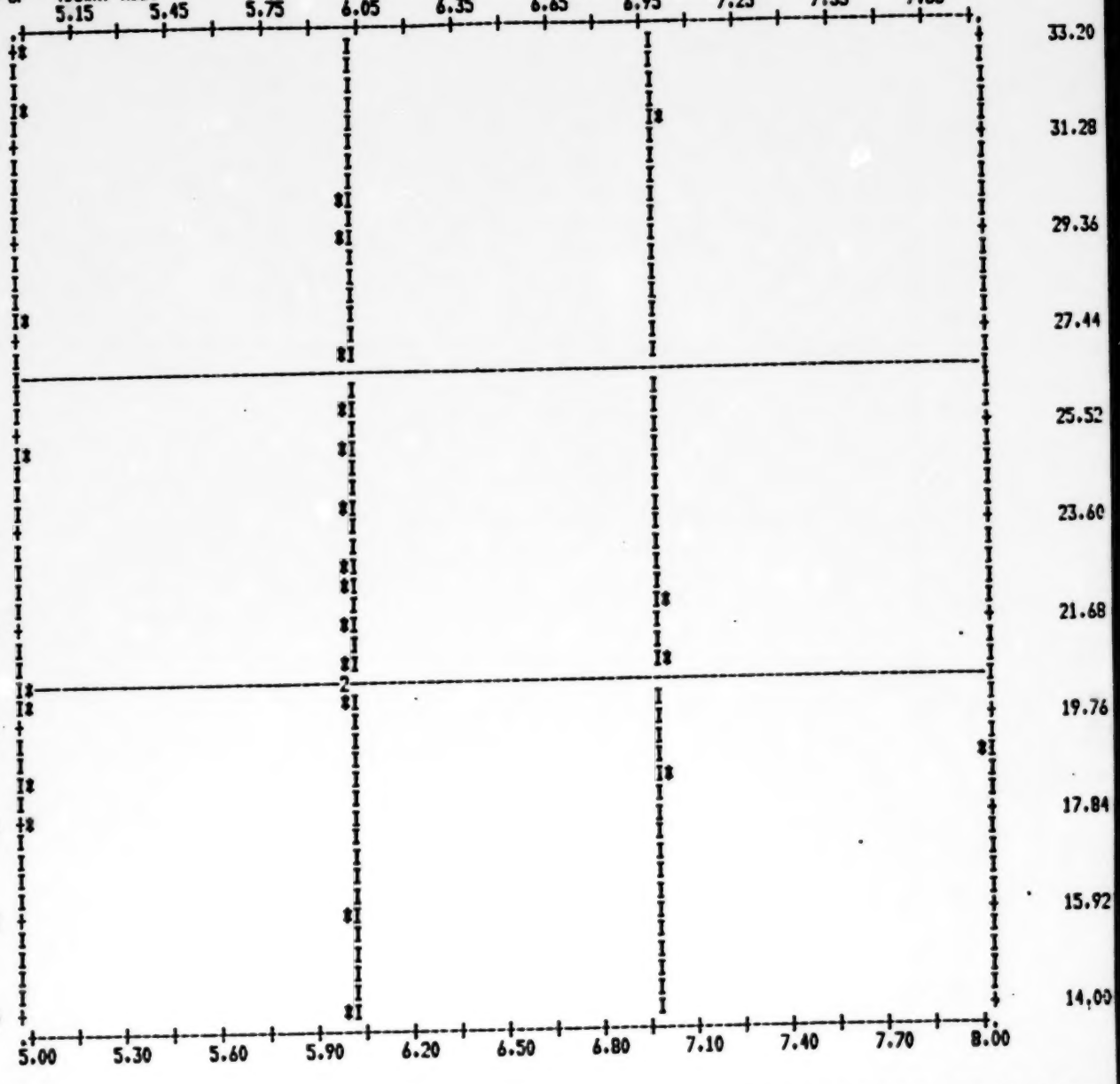


LINEAR REGRESSION OF CAIRNS FURNACE CYCLES VS CALGARY DEGREE DAYS

STATISTICS..

CORRELATION (R)-	0.27553	R SQUARED -	0.07592	SIGNIFICANCE -	0.15586
STD ERR OF EST -	5.27359	INTERCEPT (A) -	16.42850	SLOPE (B) -	0.22551
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

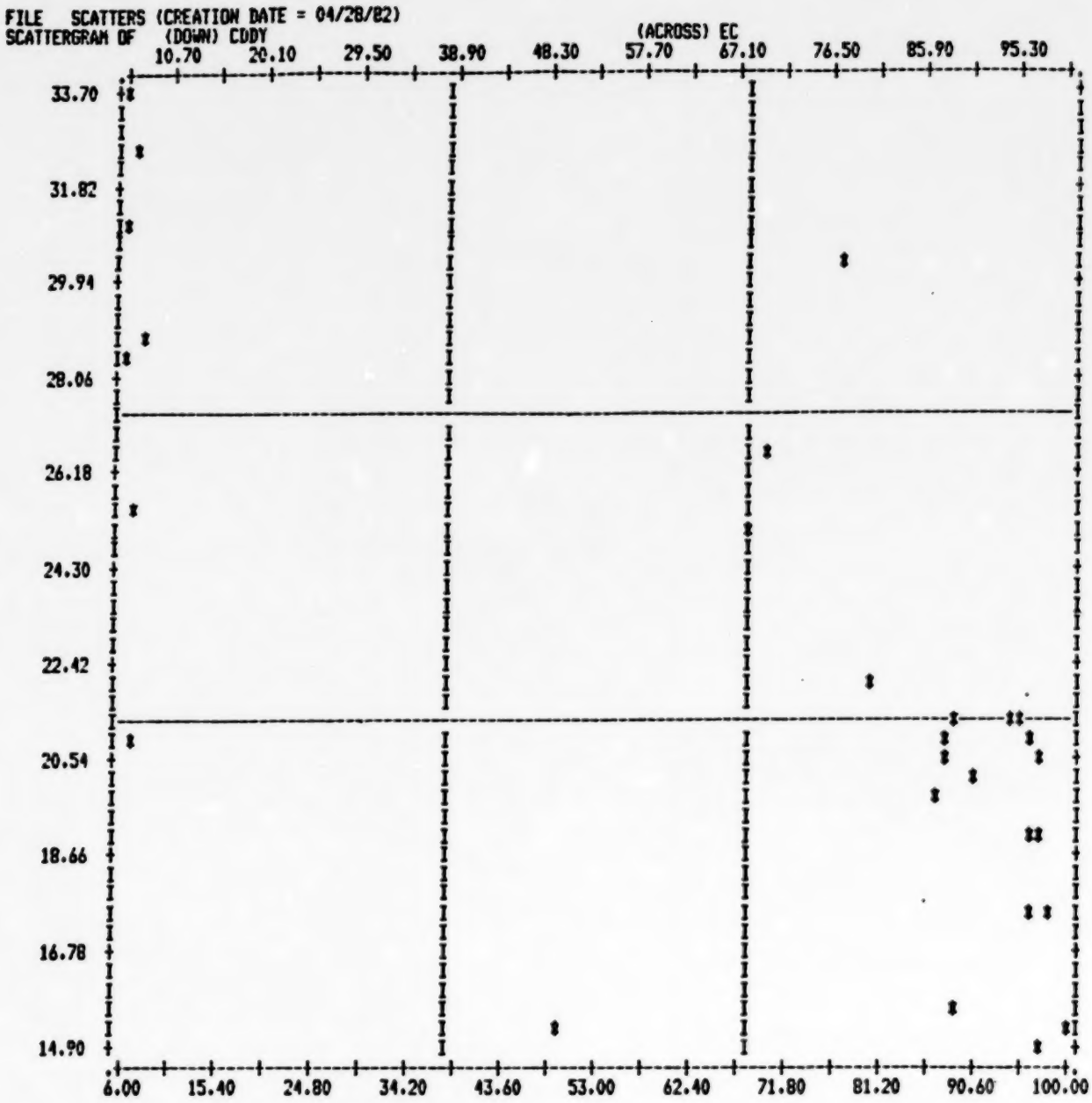
FILE SCATTERS (CREATION DATE = 04/28/82)
SCATTERGRAM OF (DOWN) KDDY (ACROSS) KC



LINEAR REGRESSION OF KANANASKIS FURNACE CYCLES VS KANANASKIS DEGREE DAYS

STATISTICS..

CORRELATION (R)-	-0.16843	R SQUARED -	0.02837	SIGNIFICANCE -	0.39157
STD ERR OF EST -	5.00884	INTERCEPT (A) -	29.65811	SLOPE (B) -	-1.09595
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0



LINEAR REGRESSION OF EDGEMONT FURNACE CYCLES VS CALGARY DEGREE DAYS

STATISTICS..

CORRELATION (R)-	-0.71805	R SQUARED -	0.51559	SIGNIFICANCE -	0.00002
STD ERR OF EST -	3.81819	INTERCEPT (A) -	29.34765	SLOPE (B) -	-0.10351
PLOTTED VALUES -	28	EXCLUDED VALUES-	0	MISSING VALUES -	0

APPENDIX D

Communications to Insulation Contractors
and Homeowners

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Re: Super-Insulated Home Information Request

The University of Calgary Kananaskis Centre has been contracted by the Federal Government to do a study on the effects of increased residential insulation on furnace sizing and efficiency.

Our initial course of action is to compile a directory of homes in the Calgary area which have recently added substantial levels or have been built with insulation levels greater than current C.M.H.C./National building code standards. Local S.A.H.A. contractors are supplying information which will enable us to contact selected homeowners and perform energy audits on the houses.

Our request, specifically, is for the following information on extensive or super insulated residential contracts which your company has performed in the last two years.

1. Type of insulation installed
2. Location of insulation (walls, roof, ceiling)
3. R value (both before and after)
4. Date of insulation
5. Client name, address, and telephone number

Your co-operation in this study will be gratefully acknowledged in the final report. We thank you in advance for your contribution.

Sincerely,

Janne Hicklin

JH/gl

We thank you very much for your assistance and cooperation with us in collecting data on your house. These data have been input to our computer program using Calgary climatic data and assumptions or estimates for leakage of heated air and inside temperature. The first two pages of printout describe the estimated performance of your house with standard assumptions of one total air change of house volume per hour and a 100 degree F temperature difference between inside and outside for the average coldest day of the year. The next two pages of printout describe the estimated performance of your house for the inside temperature as measured, and air leakage as estimated during our visit to your house. The last two pages of printout describe the estimated performance of your house with weatherstripping and caulking applied and a night setback automatic thermostat installed. You may wish to compare the estimated annual cost of natural gas for space heating between the three computer runs and your actual bills (with allowance for gas heated water) to see how your house compares with the average, and the dollar savings available with upgraded weatherstripping and temperature control. We will be happy to answer any questions which you may have regarding the additional information on the printout.

Much of the work which we are doing at the Kananaskis Centre relates to energy conservation in residential dwellings. The parameters which we measured in your house did not meet the criteria for this particular study (we were seeking houses to represent a specific range of furnace performance). However, we will keep the data collected on file and may contact you in the future regarding another project involving home energy.

Again, we thank you - your cooperation is much appreciated.

The Kananaskis Centre for Environmental Research,

Michael J. Youso
Research Associate

Janne Hicklin
Research Assistant

We thank you very much for your assistance and cooperation with us in collecting data on your house. These data have been input to our computer program using Calgary climatic data and assumptions or estimates for leakage of heated air and inside temperature. The first two pages of printout describe the estimated performance of your house with standard assumptions of one total air change of house volume per hour and a 100 degree F temperature difference between inside and outside for the average coldest day of the year. The next two pages of printout describe the estimated performance of your house for the inside temperature as measured, and air leakage as estimated during our visit to your house. The last two pages of printout describe the estimated performance of your house with weatherstripping and caulking applied and a night setback automatic thermostat installed. You may wish to compare the estimated annual cost of natural gas for space heating between the three computer runs and your actual bills (with allowance for gas heated water) to see how your house compares with the average, and the dollar savings available with upgraded weatherstripping and temperature control. We will be happy to answer any questions which you may have regarding the additional information on the printout.

Based upon the results of this analysis, we have selected your house as one of five houses in the Calgary area which meet the criteria of our study. With your cooperation, we wish to proceed with a four week monitoring program. The monitoring will involve:

1) An initial visit: to install a small chart recorder and a thermograph to automatically record temperature and furnace operation. The thermograph charts will require changing which we will arrange to do at convenient weekly intervals.

2) Another visit: to measure the rates at which warm air moves through and out of the house. This involves approximately four hours, preferably on a cold day when there is a great difference in temperature between outside and inside.
We will also coordinate with a representative from the gas company who will measure the efficiency of your furnace. These results will be available for your interest.

..../2

For the test period we would also like to schedule house temperatures with the use of a night setback thermostat. Scheduling and setback temperatures will be adjusted to levels which meet your occupancy requirements. At the conclusion of the full testing period, you will have the option of retaining this thermostat in exchange for your participation. We ask that you will agree to make no adjustments to the instrumentation without consulting us beforehand so that we may adjust our calculations accordingly.

If you have no initial objections and are interested in participating in this study, we would like to arrange an interview at your earliest convenience to explain the testing procedure in further detail and to coordinate a mutually appropriate schedule. It is understood that if, at any time during the testing period (March 8 - April 8) you wish to withdraw from involvement in this project that you are free to do so. It is further understood that the instrumentation involved in this project is the property of the U. of C. and will be removed at the end of the testing period.

Again, thank you. We sincerely appreciate your cooperation.

The Kananaskis Centre for Environmental Research,

Michael J. Youso
Research Associate

Janne Hicklin
Research Assistant

APPENDIX E

Heating Load Analyses for Houses Surveyed

U of C KANANASKIS CENTRE

BUILDING ENERGY DESIGN ANALYSIS

A program to calculate theoretical heat loss of low energy buildings,
modified from NRC DBR-R. Dumont(1981) by U of C KANANASKIS-M. Youso

********** DESIGN INPUT DATA **********

SRC FURNACE PERFORMANCE EVALUATION
Engineered Home; 1981 3-level split; tight v.b.; 100F design temp diff

DESIGN TEMPERATURE: -33 DEGREES CELSIUS
MAIN FLOOR TEMP 22.5 BASEMENT TEMP 18 GROUND WATER TEMP 4
DESIGN TEMP DIFF (ABOVE GROUND) 55.5 (BELOW GROUND) 14 DEG C

****U of C KANANASKIS CENTRE*******BUILDING ENERGY DESIGN ANALYSIS****

ELEMENT	AREA M2	RSI VALUE M2-DEGC/W	HT LOSS W/DEG C	SEASONAL % HT LOSS
CEILING	114.00	7.80	14.62	5.39
WALLS	219.00	6.00	36.50	13.47
WINDOWS,S	22.60	0.36	62.78	23.16
WINDOWS,NON-S	5.10	0.36	14.17	5.23
DOORS	7.00	2.40	2.92	1.08
BSMENT,AB.GD.	20.00	3.40	5.88	2.17
BSMENT,BL.GD.	85.00	3.80	18.16	5.36
FLOOR	105.00	0.36	49.53	14.62
AIR CHANGE	----	----	80.05	29.53

BUILDING VOLUME(M3)= 770 AIR CHANGE/HR: HEATED= 0.34 TOTAL= 0.42

HT LOSS ALL WINDOWS	(W/DEG C)	76.94
HT LOSS ABV GND,EXCL ALL WINDW	(W/DEG C)	139.96
HT LOSS BELOW GRADE WALLS	(W/DEG C)	18.16
HT LOSS BELOW GRADE FLOOR	(W/DEG C)	49.53
TOTAL HT LOSS: EFFECTIVE UA	(W/DEG C)	271.06
AVG HT TRANSMITTANCE ABV GND	(W/M2-DEG C)	0.56

TOTAL HEAT LOSS 12985(WATTS) 44320(BTU/HR) AT DESIGN TEMP: -33 DEG C

VOLUME FOR THE BUILDING (CUBIC METRES) M3= CU. FT./35.31
AREA FOR ELEMENT OF THE BUILDING (SQ. METRES) M2= SQ. FT./10.76
HEAT RESISTANCE OF ELEMENT (M2-C/W) RSI= R/5.678
HEAT LOSS OF ELEMENT (WATTS) WATTS * 3.413 = BTU/HR

U of C KANANASKIS CENTRE

BUILDING ENERGY DESIGN ANALYSIS

A program to calculate theoretical heat loss of low energy buildings,
modified from NRC DBR-R. Dumont(1981) by U of C KANANASKIS-M. Youso

********** DESIGN INPUT DATA **********

SRC FURNACE PERFORMANCE EVALUATION
Kananaskis 4A; 1968 open beam w/ loft; 1 ac/hr; 100F design temp diff

DESIGN TEMPERATURE: -33 DEGREES CELSIUS
MAIN FLOOR TEMP 22.5 BASEMENT TEMP 18 GROUND WATER TEMP 4
DESIGN TEMP DIFF (ABOVE GROUND) 55.5 (BELOW GROUND) 14 DEG C

****U of C KANANASKIS CENTRE*******BUILDING ENERGY DESIGN ANALYSIS****

ELEMENT	AREA M2	RSI VALUE M2-DEGC/W	HT LOSS W/DEG C	SEASONAL % HT LOSS
CEILING	66.40	1.10	60.36	20.87
WALLS	98.80	2.70	36.59	12.65
WINDOWS,S	1.80	0.36	5.00	1.73
WINDOWS,NON-S	7.30	0.36	20.28	7.01
DOORS	1.81	0.50	3.62	1.25
BSMENT,AB.GD.	35.50	1.00	35.50	12.28
BSMENT,BL.GD.	21.30	0.31	17.90	4.95
FLOOR	54.70	0.00	31.06	8.59
AIR CHANGE	----	----	88.68	30.66

BUILDING VOLUME(M3)= 288 AIR CHANGE/HR: HEATED= 1.00 TOTAL= 1.00

HT LOSS ALL WINDOWS	(W/DEG C)	25.28
HT LOSS ABV GND,EXCL ALL WINDW	(W/DEG C)	224.76
HT LOSS BELOW GRADE WALLS	(W/DEG C)	17.90
HT LOSS BELOW GRADE FLOOR	(W/DEG C)	31.06
TOTAL HT LOSS: EFFECTIVE UA	(W/DEG C)	289.21
AVG HT TRANSMITTANCE ABV GND	(W/M2-DEG C)	1.18

TOTAL HEAT LOSS 14562(WATTS) 49701(BTU/HR) AT DESIGN TEMP: -33 DEG C

VOLUME FOR THE BUILDING (CUBIC METRES) M3= CU. FT./35.31
AREA FOR ELEMENT OF THE BUILDING (SQ. METRES) M2= SQ. FT./10.76
HEAT RESISTANCE OF ELEMENT (M2-C/W) RSI= R/5.678
HEAT LOSS OF ELEMENT (WATTS) WATTS * 3.413 = BTU/HR

U of C KANANASKIS CENTRE

BUILDING ENERGY DESIGN ANALYSIS

A program to calculate theoretical heat loss of low energy buildings,
modified from NRC DBR-R. Dumont(1981) by U of C KANANASKIS-M. Youso

********** DESIGN INPUT DATA **********

SRC FURNACE PERFORMANCE EVALUATION
Crous Residence: 1952 Bungalow: 1 ac/hr; 100F design temp diff

DESIGN TEMPERATURE: -33 DEGREES CELSIUS
MAIN FLOOR TEMP 22.5 BASEMENT TEMP 18 GROUND WATER TEMP 4
DESIGN TEMP DIFF (ABOVE GROUND) 55.5 (BELOW GROUND) 14 DEG C

****U of C KANANASKIS CENTRE*******BUILDING ENERGY DESIGN ANALYSIS****

ELEMENT	AREA M2	RSI VALUE M2-DEGC/W	HT LOSS W/DEG C	SEASONAL % HT LOSS
CEILING	130.00	7.00	18.57	3.53
WALLS,S	26.90	1.20	22.42	4.26
WALLS,NON-S	79.20	1.20	66.00	12.55
WINDOWS,S	7.20	0.36	20.00	3.80
WINDOWS,NON-S	11.38	0.36	31.61	6.01
DOORS	3.50	0.36	9.72	1.85
BSMENT,AB.GD.	41.70	0.47	88.72	16.88
BSMENT,BL.GD.	74.30	0.47	55.04	8.38
FLOOR	130.00	0.28	63.73	9.70
AIR CHANGE	----	----	173.66	33.03

BUILDING VOLUME(M3)= 563 AIR CHANGE/HR: HEATED= 1.00 TOTAL= 1.00

HT LOSS ALL WINDOWS	(W/DEG C)	51.61
HT LOSS ABV GND,EXCL ALL WINDW	(W/DEG C)	379.10
HT LOSS BELOW GRADE WALLS	(W/DEG C)	55.04
HT LOSS BELOW GRADE FLOOR	(W/DEG C)	63.73
TOTAL HT LOSS: EFFECTIVE UA	(W/DEG C)	525.72
AVG HT TRANSMITTANCE ABV GND	(W/M2-DEG C)	1.44

TOTAL HEAT LOSS 25567(WATTS) 87260(BTU/HR) AT DESIGN TEMP: -33 DEG C

VOLUME FOR THE BUILDING (CUBIC METRES) M3= CU. FT./35.31
AREA FOR ELEMENT OF THE BUILDING (SQ. METRES) M2= SQ. FT./10.76
HEAT RESISTANCE OF ELEMENT (M2-C/W) RSI= R/5.678
HEAT LOSS OF ELEMENT (WATTS) WATTS * 3.413 = BTU/HR

U of C KANANASKIS CENTRE

BUILDING ENERGY DESIGN ANALYSIS

A program to calculate theoretical heat loss of low energy buildings,
modified from NRC DBR-R. Dumont(1981) by U of C KANANASKIS-M. Youso

********** DESIGN INPUT DATA **********

SRC FURNACE PERFORMANCE EVALUATION
Rath Rental; 1920's two story; 1 ac/hr; 100F design temp diff

DESIGN TEMPERATURE: -33 DEGREES CELSIUS
MAIN FLOOR TEMP 22.5 BASEMENT TEMP 20 GROUND WATER TEMP 4
DESIGN TEMP DIFF (ABOVE GROUND) 55.5 (BELOW GROUND) 16 DEG C

****U of C KANANASKIS CENTRE*******BUILDING ENERGY DESIGN ANALYSIS****

ELEMENT	AREA M2	RSI VALUE M2-DEGC/W	HT LOSS W/DEG C	SEASONAL % HT LOSS
CEILING	53.30	5.30	10.06	2.35
WALLS	159.40	2.00	79.70	18.65
WINDOWS,S	6.16	0.17	36.24	8.48
WINDOWS,NON-S	6.63	0.17	39.00	9.13
DOORS	6.30	0.30	21.00	4.91
BSMENT,AB.GD.	29.00	0.47	61.70	14.44
BSMENT,BL.GD.	49.00	0.47	36.30	6.80
FLOOR	53.30	0.36	25.14	4.71
AIR CHANGE	----	----	130.48	30.53

BUILDING VOLUME(M3)= 423 AIR CHANGE/HR: HEATED= 1.00 TOTAL= 1.00

HT LOSS ALL WINDOWS	(W/DEG C)	75.24
HT LOSS ABV GND,EXCL ALL WINDW	(W/DEG C)	302.94
HT LOSS BELOW GRADE WALLS	(W/DEG C)	36.30
HT LOSS BELOW GRADE FLOOR	(W/DEG C)	25.14
TOTAL HT LOSS: EFFECTIVE UA	(W/DEG C)	427.32
AVG HT TRANSMITTANCE ABV GND	(W/M2-DEG C)	1.45

TOTAL HEAT LOSS 21971(WATTS) 74989(BTU/HR) AT DESIGN TEMP: -33 DEG C

VOLUME FOR THE BUILDING (CUBIC METRES) M3= CU. FT./35.31
AREA FOR ELEMENT OF THE BUILDING (SQ. METRES) M2= SQ. FT./10.76
HEAT RESISTANCE OF ELEMENT (M2-C/W) RSI= R/5.678
HEAT LOSS OF ELEMENT (WATTS) WATTS * 3.413 = BTU/HR

U of C KANANASKIS CENTRE

BUILDING ENERGY DESIGN ANALYSIS

A program to calculate theoretical heat loss of low energy buildings,
modified from NRC DBR-R. Dumont(1981) by U of C KANANASKIS-M. Youso

********** DESIGN INPUT DATA **********

SRC FURNACE PERFORMANCE EVALUATION
White Residence; 1956 bungalow; 1 ac/hr; 100F design temp diff

DESIGN TEMPERATURE: -33 DEGREES CELSIUS
MAIN FLOOR TEMP 22.5 BASEMENT TEMP 20 GROUND WATER TEMP 4
DESIGN TEMP DIFF (ABOVE GROUND) 55.5 (BELOW GROUND) 16 DEG C

****U of C KANANASKIS CENTRE*******BUILDING ENERGY DESIGN ANALYSIS****

ELEMENT	AREA M2	RSI VALUE M2-DEGC/W	HT LOSS W/DEG C	SEASONAL % HT LOSS
CEILING	97.90	6.70	14.61	4.07
WALLS	90.00	1.20	75.00	20.88
WINDOWS,S	0.00	0.36	0.00	0.00
WINDOWS,NON-S	13.95	0.36	38.75	10.79
DOORS	3.46	0.36	9.61	2.68
BSMENT,AB.GD.	46.61	2.10	22.20	6.18
BSMENT,BL.GD.	49.12	2.10	16.48	3.67
FLOOR	97.90	0.28	47.99	10.69
AIR CHANGE	----	----	147.45	41.05

BUILDING VOLUME(M3)= 478 AIR CHANGE/HR: HEATED= 1.00 TOTAL= 1.00

HT LOSS ALL WINDOWS	(W/DEG C)	38.75
HT LOSS ABV GND,EXCL ALL WINDW	(W/DEG C)	268.86
HT LOSS BELOW GRADE WALLS	(W/DEG C)	16.48
HT LOSS BELOW GRADE FLOOR	(W/DEG C)	47.99
TOTAL HT LOSS: EFFECTIVE UA	(W/DEG C)	359.19
AVG HT TRANSMITTANCE ABV GND	(W/M2-DEG C)	1.22

TOTAL HEAT LOSS 18104(WATTS) 61789(BTU/HR) AT DESIGN TEMP: -33 DEG C

VOLUME FOR THE BUILDING (CUBIC METRES) M3= CU. FT./35.31
AREA FOR ELEMENT OF THE BUILDING (SQ. METRES) M2= SQ. FT./10.76
HEAT RESISTANCE OF ELEMENT (M2-C/W) RSI= R/5.678
HEAT LOSS OF ELEMENT (WATTS) WATTS * 3.413 = BTU/HR

U of C KANANASKIS CENTRE

BUILDING ENERGY DESIGN ANALYSIS

A program to calculate theoretical heat loss of low energy buildings, modified from NRC DBR-R. Dumont(1981) by U of C KANANASKIS-M. Youso

********** DESIGN INPUT DATA **********

SRC FURNACE PERFORMANCE EVALUATION
NU WEST HOME; 1981 single story; air/air heat exch; tight v.b.;
100F design temp diff

DESIGN TEMPERATURE: -33 DEGREES CELSIUS
MAIN FLOOR TEMP 22.5 BASEMENT TEMP 18 GROUND WATER TEMP 4
DESIGN TEMP DIFF (ABOVE GROUND) 55.5 (BELOW GROUND) 14 DEG C

****U of C KANANASKIS CENTRE*******BUILDING ENERGY DESIGN ANALYSIS****

ELEMENT	AREA M2	RSI VALUE M2-DEGC/W	HT LOSS W/DEG C	SEASONAL % HT LOSS
CEILING	149.40	7.00	21.34	9.35
WALLS,S	44.20	3.70	11.95	5.23
WALLS,NON-S	144.40	5.45	26.51	11.61
WINDOWS,S	9.20	0.57	16.14	7.07
WINDOWS,NON-S	9.50	0.57	16.67	7.30
DOORS	6.00	2.40	2.50	1.10
BSMENT,AB.GD.	9.80	3.50	2.80	1.23
BSMENT,BL.GD.	60.80	3.50	13.88	4.86
FLOOR	112.00	0.36	52.83	18.52
AIR CHANGE	----	----	76.99	33.73

BUILDING VOLUME(M3)= 737 AIR CHANGE/HR: HEATED= 0.34 TOTAL= 0.43

HT LOSS ALL WINDOWS	(W/DEG C)	32.81
HT LOSS ABV GND,EXCL ALL WINDW	(W/DEG C)	142.09
HT LOSS BELOW GRADE WALLS	(W/DEG C)	13.88
HT LOSS BELOW GRADE FLOOR	(W/DEG C)	52.83
TOTAL HT LOSS: EFFECTIVE UA	(W/DEG C)	228.27
AVG HT TRANSMITTANCE ABV GND	(W/M2-DEG C)	0.47

TOTAL HEAT LOSS 10640(WATTS) 36316(BTU/HR) AT DESIGN TEMP: -33 DEG C

VOLUME FOR THE BUILDING (CUBIC METRES) M3= CU. FT./35.31
AREA FOR ELEMENT OF THE BUILDING (SQ. METRES) M2= SQ. FT./10.76
HEAT RESISTANCE OF ELEMENT (M2-C/W) RSI= R/5.678
HEAT LOSS OF ELEMENT (WATTS) WATTS * 3.413 = BTU/HR

POOR

QUALITY

ORIGINAL